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OHD 020273819

March 29, 1988

Mr. Jerry Lenssen
US Environmental Protection Agency
5HS-JCK-13
2305 Dearborn Street
Chicago, IL 60604

Dear Jerry:

Attached you will find the Chemical Waste Management Quality Assurance Manual for soil materials used at all Chemical Waste Management sites. I believe this should answer Condition 13 of your conditional approval letter. If there are any questions, please do not hesitate to contact us.

Yours very truly,

CHEMICAL WASTE MANAGEMENT

Dean D. Nelson, P.E.
Regional Environmental Engineer
Eastern Region

DDN:dm

Attachment

TITLE: 021

cc: Dana Lockwood, w/o attach.
Dave Petrovski, w/attach.
Craig Liska, w/attach.

COPY 2

QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF THE SOIL COMPONENTS OF LINING AND FINAL COVER SYSTEMS

JUNE 1986

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1. INTRODUCTION

This manual describes construction quality assurance (CQA) procedures for the installation of the soil components of lining and final cover systems in hazardous waste landfills and surface impoundments constructed and operated by Chemical Waste Management, Inc (CWMI). The term "Quality Assurance," used in its broadest sense, is based upon the concept of "Quality Control" (defined in Section 2.1). This manual addresses only the soil components of the liner and cover systems. Design guidelines for geomembranes, geotextiles, piping, or structures are covered in other documents.

All parties listed in Section 2.1, as they become involved in a lining system project, will be issued a copy of this Construction Quality Assurance Manual from the Owner, Project Manager, or Construction Quality Assurance Engineer and Monitor(s). They will also be given other quality assurance documents specifically prepared for the project.

This manual is to be the basis of the overall CQA program for soil components of lining and cover systems. Site-specific addenda must be prepared by the CWMI Quality Assurance Project Manager, the CQA Engineer, and other affected parties.

The overall goals of this construction quality assurance program are to ensure that proper construction techniques and procedures are used and to verify that the materials and installation techniques used meet project specifications. Additionally, the program will (1) identify and define problems that may occur during construction, and (2) ensure that these problems are corrected before the construction is complete. At completion of the work, the program will culminate in a certification report which documents that the earthwork has been constructed in accordance with design standards and specifications. This certification is the responsibility of the Construction Quality Assurance Consultant.

The main emphasis of the Construction Quality Assurance Manual is careful documentation during the entire quality assurance process, from the selection of materials through the installation of final cover.

2. DEFINITION OF OPERATIONS AND RESPONSIBILITIES

2.1 Definitions

This manual has been developed for the application of construction quality assurance and quality control procedures to the soil components of liner and final cover systems. Construction quality assurance and quality control are defined as follows:

Construction Quality Assurance	A planned and systematic application of all means and actions designed to provide adequate confidence that items or services meet design and specifications requirements and will perform satisfactorily in service. Construction quality assurance includes quality control. In the context of liner installation, construction quality assurance refers to means and actions employed by the Project Manager and the Construction Quality Assurance Engineer and Monitor to ensure conformity of the liner installation with guidelines set forth in the Construction Quality Assurance Manual.
Quality Control	Those actions which provide a means to measure and regulate the characteristics of an item or service to design and specifications requirements: In the context of liner installation, quality control refers to those actions taken by the Earthwork Contractor and the Construction Quality Assurance Engineer and Monitor to ensure that the product and the workmanship meet the requirements of the plans and specifications.

Design Engineer	An individual or firm responsible for the design, drawings, plans, and specifications of the lining system and the supporting soil.
Earthwork Contractor	The individual or firm, also referred to as the "Contractor," responsible for the site preparation (clearing and grubbing, excavation backfilling, general earthfill, etc.), and placing earth and granular materials composing the soil components of lining systems. The Contractor may also be responsible for locating and transporting the required earth and granular materials, concrete, piping, and other work, as outlined in the specifications and noted on contract drawings.
Construction Quality Assurance Consultant	The firm or individual, also referred to as "Consultant", responsible for observing, testing, and documenting activities related to construction quality assurance and quality control during installation of the soil components of the liner system. In this manual, the term CQA Engineer is used interchangeably with CQA Consultant. The CQA Monitor(s) are on-site employees of the CQA Consultant. The Consultant is also responsible for issuing the summary certification and certification reports, which must bear the seal of a registered professional engineer.

Owner	The individual or firm that owns and/or operates the hazardous waste facility: In this manual, the term "Owner" means Chemical Waste Management, Inc. (CWMI) or its subsidiary or division, and applies equally to "Operator," i.e., the party responsible for operating the facility.
Project Manager	The official representative of the Owner: In this manual, the term "Project Manager" shall mean a duly authorized employee or representative of the Owner and shall apply equally to the "Construction Coordinator," i.e., the individual in charge of coordinating field activities.
CQA Project Manager	The official CQA representative of the Owner: In this manual, the term "CQA Project Manager" shall mean a duly authorized employee or representative of the Owner in charge of CQA activities.
Project Design Plans and Specifications	Includes all project specifications and engineering drawings and any modifications developed at the pre-construction and initial meetings.
Site Specific Addenda	Those documents and/or modifications to the CQA Manual(s) that are developed to address specific design requirements for a given project.

2.2 Scope

The work addressed in this Quality Assurance Plan is intended to facilitate proper construction of all soil components of double-lined hazardous waste disposal cells and surface impoundments. All work shall be constructed in accordance with the project design plans and specifications or as required by the Owner or his representative. In order to support these goals, the Earthwork Contractor and the CQA Engineer shall comply with the requirements given in the following section.

2.3 Qualifications and Responsibilities

2.3.1 Earthwork Contractor

The Earthwork Contractor is responsible for constructing the lining and final cover systems in conformance to the project design plans and specifications. The Earthwork Contractor shall provide the following information to the Project Manager prior to confirmation of any contractual agreements:

- a demonstration of bonding capability and a list of outstanding contracts
- a list of at least five comparable projects for which the following information shall be provided for each project:
  - name of the facility, its location, and date of installation
  - name of project manager or contact person for the installation
  - description and purpose of installation and definition of contractor's scope of work
- a list of readily available equipment required to perform the work (i.e., scrapers, graders, scarifiers, compactors, disking equipment, water trucks, and admixing equipment, if required)

2.3.2 Construction Quality Assurance Monitor(s)

The CQA Monitor shall observe and document the activities of the Contractor in sufficient detail and with sufficient continuity to provide a high level of confidence that the work product complies with the design drawings and specifications. In addition, the CQA Monitor shall perform and repeat tests, as necessary, to provide a high degree of certainty that the physical/mechanical characteristics of the soil components of the lining system meet or exceed all specifications.

The CQA Monitor shall issue a daily report of earthwork activities. These reports shall include, as a minimum, visual observations and test results. In addition, problems encountered and resolved shall be documented. Construction reports summarizing significant events, as well as addressing all problems encountered and their solutions, shall be periodically issued to the Project Manager. The frequency of these reports shall be established at the pre-construction meeting.

The CQA Monitor is required to inform the Contractor, or his representative, in a timely manner, of any difference of the CQA Monitor's interpretation of the plans and specifications from the Contractor's interpretation of any actual or suspected work deficiencies as soon as they come to the CQA Monitor's attention (when the CQA Monitor has properly and adequately assessed the situation).

The CQA Monitor shall establish a program of quick and ready access to the Contractor at all times. Communication must be frequent, and the lines of communication must be specifically established at the preconstruction meeting and followed.

The CQA Consultant shall furnish quality control personnel, and shall be a qualified engineering firm. Prior to confirmation of any contractual agreements, the CQA Consultant shall provide the Project Manager with the following written information:

- corporate information:
  - a brief corporate history
  - proof of insurance, including:

    professional liability

    "umbrella" coverage

    other coverage as required by state and local statutes and/or proposed contractual agreement

- inspection capabilities:
  - a summary of the firm's experience with observation and testing of earthwork activities in general, and soil components of lining systems for waste facilities, in particular
  - a summary of the firm's experience in construction quality assurance and quality control, particularly experience in the inspection of soil components of liner systems for waste disposal and/or storage facilities

- personnel:
  - resumes of personnel to be involved in the project, including supervising engineer, resident engineers, and CQA Monitors.
  - proof of an engineering degree and/or Professional Engineering registration in the project state, for the supervising engineer
  - specific experience of personnel in inspecting the installation of the soil components of lining systems, including a list of major projects and a chronological employment history with dates

3. MEETINGS

3.1 Resolution Meeting

Following the completion of the design plans and specifications for the project, a resolution meeting shall be held. The Design Engineer, Owner, Project Manager, and CQA Monitor shall all be present at this meeting. The purpose of this meeting is to:

- o provide all parties with any relevant documents
- o review the plans and specifications provided by the Design Engineer
- o make any appropriate modifications to the construction quality assurance plan (i.e., ensure that site-specific considerations are added to the plans or specifications)
- o review of the construction quality assurance plan and quality control procedures
- o develop site specific addenda for the proposed project
- o review and assign responsibilities of each party
- o establish procedures for documentation and reporting of information
- o establish methods for distribution and storage of documents and reports
- o prepare a time schedule for all operations
- o establish work area security and safety protocol
- o discuss and select the qualified Earthwork Contractors who will be asked to bid
- o review any special permit conditions or state/federal requirements that may need to be included in CQA work
- o select testing equipment and review protocol for testing and placement of the soil materials

The meeting shall be documented by the CQA Monitor or a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

3.2 Pre-Construction Meeting

A pre-construction meeting shall be held at the site. At a minimum, the meeting shall be attended by the Earthwork Contractor, the CQA Monitor, and the Project Manager. The resolution meeting and the pre-construction meeting may be held concurrently. The purpose of the pre-construction meeting is to:

- o discuss any appropriate modification of the construction quality assurance plan (i.e., ensure that site-specific considerations are added, and review any special permit conditions or state/federal requirements that may need to be included)
- o review the responsibilities of each party
- o review lines of authority and communication
- o review procedures for documentation and reporting of information
- o review distribution and storage of documents and reports
- o establish protocol for testing
- o establish protocol for handling construction deficiencies, and repairs and retesting
- o conduct a site walk-around to discuss work plans and inspect material handling, borrow, and stockpiling locations
- o establish areas for stockpiling and development of test fill, as well as areas that may be required for temporary storage or use
- o review a time schedule for all operations
- o review work area security and safety protocol
- o discuss and establish procedures for material processing (moisture condition, soil blending, etc.)
- o discuss and establish procedures for care and control of water, protection from wind, drying, dust control, and general liner protection and housekeeping

- o review health and safety requirements applicable to all parties
- o develop site-specific addenda to the Construction Quality Assurance Manual for the proposed project

The meeting shall be documented by the CQA Monitor or a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties prior to the start of construction.

3.3 Progress Meetings

A progress meeting shall be held daily at the work area. At a minimum, the meeting shall be attended by the Earthwork Contractor and the CQA Monitor. The purpose of the meeting is to:

- o review the work activity and location for the day
- o discuss the Earthwork Contractor's personnel and equipment assignment for the day
- o review the previous day's activity and accomplishments
- o review the work schedule
- o discuss possible problems
- o review any new test data

The meeting shall be documented in the CQA Monitor's daily report.

3.4 Problem or Work Deficiency Meeting

A special meeting shall be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting shall be attended by the Earthwork Contractor, the Project Manager, and the CQA Monitor. If the problem requires a design modification, the Design Engineer should also be present. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency
- review alternative solutions
- implement an action plan to resolve the problem or deficiency

The meeting shall be documented by the CQA Monitor.

4. EARTH MATERIALS QUALITY ASSURANCE

4.1 General

Construction of the hazardous waste disposal cell, surface impoundment, or specified earthwork must be in accordance with the project plans and specifications. This, in part, shall be accomplished by the judicious use of a quality control testing program. Specifically, the quality control testing program shall be conducted in two categories:

- pre-construction testing
- construction testing

Quality control testing within these categories shall consist of the following:

- material evaluation
- construction quality evaluation
- hydraulic conductivity evaluation
- special testing

4.2 Material Evaluation

4.2.1 General

The types of soils used in lining systems include general earthfill, clay liner and cover materials, drainage materials, protective cover materials, and vegetative cover soil. General descriptions of each of these materials are presented in Section 4.2.3. Prior to construction, sources for each of these materials shall be identified, and samples of each material from each source shall be tested to determine whether they

meet project specifications. The sources shall be ranked for acceptability based on test results, unit material price, and transportation cost.

This manual focuses on material tests conducted during the construction phase. These tests must be performed to confirm that the procured material meets project specifications before it is accepted for construction. Further material testing is necessary if alternative borrow material is required during construction or if soils are processed on site (i.e., when drainage materials are washed to increase their permeability or when clay liner materials are mixed with bentonite or other admix material). All material evaluation tests are to be performed in a geotechnical laboratory which has been approved for use by the Owner or the Project Manager or their representative.

4.2.2 Laboratory Soils Tests

Tests to confirm the adequacy of procured materials shall be performed on each material from each source area. All tests shall be documented, and the material shall be accepted or rejected according to the results of these tests. The following tests shall be performed in the evaluation of material properties for construction purposes (Tables 1 and 2 present the type and minimum number of tests required for each type of material):

TEST	ASTM Standard No.
o Laboratory Determination of Water (moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures	D2216-80
o Particle-Size Analysis of Soils	D422-63
o Amount of Material in Soils Finer than the No. 200 Sieve	D1140-54
o Laboratory Determination of Liquid Limit, Plastic Limit and Plasticity Index of Soil	D4318-83

- o Shrinkage Factors of Soils D427-83
- o Specific Gravity of Soils D854-83

4.2.3 Soils Selection Criteria

All soil materials used during construction shall meet the following general criteria, unless otherwise indicated in the project specifications, and/or site specific addendum:

4.2.3.1 General Earthfill: General earthfill shall consist of random, well-graded granular or cohesive material taken from on-site or approved off-site excavations or stockpiles. This material shall be relatively free of organics (less than 3 percent by volume), trash, clayballs (larger than 6 inches), or other deleterious matter. If required, this material shall be processed such that it does not contain particles greater than 6 inches in least dimension.

4.2.3.2 Clay Liner/Cover Material

4.2.3.2.1 Natural Soil: Soils used in primary and secondary clay liners, and in the final clay cover shall consist of a clean, select material free of organics, trash, excess silt, or other deleterious matter. It should be classified according to the Unified Soil Classification System as CL or CH. Organic soils shall not be used as clay liner material. Sand and silt soils (SC, ML, and MH) may be suitable and may require bentonite additions to achieve the specified permeability described in 4.2.3.2.2 below. If required, the clay liner/ cover materials shall be processed so that it does not contain particles greater then 4 inches in the least dimension. The clay liner shall have a compacted coefficient of permeability equal to or less than 1×10^{-7} cm/sec.

4.2.3.2.2 Soil/Bentonite Admix Material: If the native on-site soil exhibits a compacted permeability of greater than 1×10^{-7} cm/sec, its permeability can be lowered to 1×10^{-7} cm/sec or less by mixing the soil with bentonite. This should be done only with the written approval of the Project Manager.

To manufacture the admixed soil, sufficient quantities of dry bentonite shall be thoroughly admixed into the soils to provide a material that will exhibit the required permeability when compacted to the specified relative compaction and moisture content. The ratio of bentonite will be adjusted in the field to reduce the soil permeability to less than 1×10^{-7} cm/sec.

The optimum soil-bentonite ratio should be established by a laboratory testing program. The testing program would include compaction tests and laboratory permeability tests on fabricated samples.

Mixing shall be performed in areas prepared near the soil borrow or construction site area. Any necessary moisture conditioning of the admix material shall be performed in the processing area at least 24 hours before its use.

The admix stockpiles shall be surface-graded and compacted to minimize drying. Any material which is allowed to dry out shall be selectively spoiled for moisture conditioning as directed by the CQA Monitor.

After approval of the soil/bentonite mixture by the Inspector as "impervious soil," the material shall be available for use in construction of clay liners or covers.

4.2.3.3 Drainage Material: Drainage materials are used in the primary and secondary leachate collection systems and in the drainage layer above the final cover. All drainage material shall consist of clean sands and/or gravels or other permeable material classified as SW, SP, GW, or GP that contain less than 5 percent (by dry weight) passing the U.S. No. 200 sieve and with 100 percent by dry weight passing the 3-inch sieve.

Gravel placed in pipe trenches shall be classified as GW or GP, contain less than 5 percent fines, and be of a gradation whereby 95 percent of the material is larger than the perforations of the drainage pipe.

All drainage layer materials shall have a coefficient of permeability equal to or greater than 1×10^{-2} cm/sec.

4.2.3.4 Protective Cover Over Geomembrane or Primary Leachate Collection System: This material may be used to protect the primary geomembrane in surface impoundments or to protect the primary leachate collection systems in landfills. It shall typically be a fine-grained earthfill having a maximum rounded or subrounded particle size of 1/4 inch in least dimension unless a protective geotextile is first placed over the geomembrane, in which case a maximum particle size of 1 inch is permissible. Processing to remove larger particles may be required. The particles shall not be angular or have sharp edges or points.

4.2.3.5 Vegetative Cover: This material shall be topsoil material and/or soil capable of providing the proper base for establishing surficial grasses for erosion protection. This material will be specified on a site-specific basis.

4.2.4 Test Fill

A test fill shall be constructed to provide field verification of the moisture/density/permeability relationships obtained from laboratory tests. The test fill shall be constructed utilizing borrow material dedicated for use in the proposed project, including any admix materials. The test fill shall be used to evaluate the following:

- o material handling and placement requirements
- o compaction equipment and procedures
- o number of passes of equipment necessary to achieve required results
- o permeability
- o provide test samples for laboratory permeability testing

The test fill shall have approximate plan dimensions of 20 feet by 60 feet and be constructed at a location designated by the Owner. The Contractor shall construct the test fill using the same equipment and procedures that will be utilized during project construction. Observation and testing shall be conducted by the CQA Monitor.

The suggested method to develop compaction criteria for the compacted clay liner/cover is detailed in Appendix B.

4.3 Construction Quality Evaluation

Construction quality evaluation shall be performed on all components of the construction. Criteria to be used for determination of acceptability of the construction work shall be as identified in the project specifications.

Construction evaluation testing shall consist of (1) inspection of the work, (2) investigations into the adequacy of layer bonding, and (3) field and laboratory tests. All field and laboratory tests shall be conducted on samples taken from material during the course of the work.

4.3.1 Inspection of the Work

Inspection of the construction work includes the following:

- inspection of the water content and other physical properties of the soil during processing, placement, and compaction
- inspection of the thickness of lifts as loosely placed and as compacted
- inspection of the action of the compaction and heavy hauling equipment on the construction surface (sheepsfoot penetration, pumping, cracking, etc.)
- inspection of the number of coverages used to compact each lift

4.3.2 Evaluation of Layer Bonding

Evaluation of layer bonding may be determined by using test pits to make visual observations. All test pits shall be excavated in a manner acceptable to the CQA Monitor. Test pits shall be at least 1 foot in depth. All pits shall be backfilled and compacted in accordance with the project specifications. The backfill shall be compacted using hand compaction equipment or other methods approved by the CQA Monitor.

4.3.3 Laboratory and Field Tests

The following laboratory test methods are typically utilized to develop data upon which acceptability evaluations can be based. Testing frequencies are presented in Tables 1 and 2.

Parameter	Method	ASTM Standard No.
Compaction (Moisture/Density Relationships using 5.5-pound hammer and 12-inch drop)	Standard Proctor Test	D698-78
Compaction (Moisture/Density Relationships using 10-pound hammer and 18-inch drop)	Modified Proctor Test	D1557-78
Liquid Limit, Plastic Limit, Plasticity Index	Atterberg Limits	D4318-83
Particle Size	Sieve Analysis Percent Passing the No. 200 sieve	D422-63 D1140-54

The following testing is typically performed in the field during construction:

Parameter	Method	ASTM Standard No.
Strength Tests	- Pocket penetrometer - Torvane shear	
Field Moisture/Density Determination	- Drive cylinder - Nuclear methods - Rubber balloon - Sand-cone method	D 2937-83* D 2922-81 D 3017-78 D 2167-66* D 1556-82

* These tests may be used to supplement sand-cone and nuclear methods.

Nuclear density methods shall be preferred for all density testing due to the ease of testing and the relatively large number of tests which can be run in a specified time. Questions concerning the accuracy of any single test shall be addressed by retesting in the same or another location. Periodic [one (1) per twenty (20) nuclear density tests, or a minimum of one (1) per day] checks using the sand-cone method shall be performed to verify the nuclear density results. Wherever a conflict exists, sand-cone results shall be accepted over nuclear density results.

At locations where the field testing indicates densities below the requirements of the specifications, the failing area shall be reworked. For clay liners where the field testing indicates the moisture content is below the requirements, the area shall be scarified, moisture conditioned, and recompacted. Alternately, at the CQA Monitor and Project Manager's option, undisturbed samples of in-place material shall be obtained and permeability and/or strength tests conducted. The density requirements may be waived if the permeability and strength tests reveal acceptable results.

Tables 2 and 3 describe in detail the types and number of tests required for each liner component during construction evaluation. Except for the subgrade, the criteria for these tests are presented in Section 4.2.3 or identified in project specifications.

4.3.4 Subgrade

During construction, the subgrade soil shall be tested to confirm that its soil characteristics are equivalent to those utilized in the design of the liner. The upper portion of the subgrade can be damaged by excess moisture (causing softening) and insufficient moisture (causing desiccation and shrinkage), or by freezing. These conditions are normally not discovered until after the design phase of the project.

At a minimum, the CQA Monitor shall determine the suitability of the subgrade for fill placement by:

- continuous visual inspection during proof-rolling
- pocket penetrometer or Torvane shear tests in suspect soil areas

The following tests may also be performed on the subgrade material (if required):

- laboratory tests
  - compaction tests (Standard Proctor) on each material type
- field tests
  - moisture/density tests - 1 per 10,000 cu yd or 10,000 sq ft
  - pocket penetrometer tests - one per moisture/density test

4.4 Hydraulic Conductivity Evaluations

As shown in Tables 1 and 2, hydraulic conductivity (permeability) evaluations shall be conducted on all materials proposed for use or used in the construction of the clay liners or runoff control berms. Hydraulic conductivity evaluations shall be performed on samples obtained from the constructed test fill and/or clay liner. Laboratory manufactured clay liner samples shall be used only for evaluation during material selection. Criteria to be used for determination of acceptability shall be as identified in this document and in the project specifications.

The following laboratory tests shall be used to assess hydraulic conductivity of materials during pre-construction:

Test	ASTM Standard No.
• Permeability of Granular Soil (Constant Head Test)	D2434-68

Since there is no ASTM method or standardized sample preparation and testing techniques for permeability, the laboratory procedures to be utilized shall be discussed by all parties at the resolution meeting (see Section 3.1). Laboratory testing of field compacted clay liner samples shall be performed on back pressure-saturated specimens in a flex-wall apparatus. A typical protocol for this type of test is included in Appendix E.

Other tests conducted on permeability samples shall consist of Atterberg limits and particle size analysis.

4.5 Special Testing

Construction evaluation involving special testing shall be conducted at the direction of the Owner or his representative, or as required by the project specifications. Special testing shall be performed on samples of the constructed clay liner or appurtenant components. Criteria used to determine acceptability shall be established by the Owner and/or his CQA representative at the pre-construction meeting and documented as part of the site specific Addenda.

Special testing shall be utilized beneath collection manhole risers or at locations otherwise deemed critical by the Owner and/or his CQA representative.

The following tests shall be performed to provide data for the evaluation:

Test	ASTM Standard No.
o Compressive Strength, Unconfined Cohesive Soils	D2166-66
o One-Dimensional Consolidation Properties of Soils	D2435-80
o Direct Shear (Consolidated, Drained)	D3080-72
o Shear, Triaxial Compression	
- Consolidated Drained (CD)*	
- Consolidated Undrained (CU)*	
- Unconsolidated Undrained (UU)	D2850-82

* For procedures for these tests, refer to:

U.S. Army Corps of Engineers (WES), 1970, "Laboratory Testing Manual," Engineering Manual 1110-2-1906.

Lambe, T.W., 1951, "Soil Testing for Engineers," Wiley, New York, NY.

4.6 Quality Control Testing Frequency

All quality control testing shall be conducted in accordance with the project specifications or as directed by the Owner and/or his CQA representative, and as documented in the site specific Addenda. Testing methods, as previously identified, shall be observed by the CQA Monitor. Documentation and reporting of test results shall be in accordance with the requirements identified in Section 5 of this manual.

Pre-construction testing shall be conducted on material samples obtained from the borrow location and/or from the stockpile(s). Pre-construction testing shall consist of material evaluation tests as described in Section 4.2.

Construction quality control testing shall be conducted on samples taken from the material during the course of the work. Construction quality testing shall consist of material evaluation tests and construction quality evaluation tests as described in Sections 4.2 and 4.3.

Routine testing frequencies for material evaluation and construction quality evaluation are presented in Tables 1, 2 and 3. In these tables, the terms "layer" and "lift" are used. These terms are defined as follows.

- A "layer" is defined as a compacted stratum composed of several lifts constructed without construction joints and without changes of grade exceeding 5 percent in any direction.
- A "lift" is defined as a constructed segment of a layer comprised of clay materials placed in a 6-inch compacted thickness.

Sampling locations shall be selected by the CQA Monitor. If necessary, the location of routine in-place density tests shall be determined using a non-biased sampling plan (attached as Appendix C).

A special testing frequency shall be used at the discretion of the Owner and/or his CQA representative when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas shall be considered when:

- o rollers slip during rolling operation
- o lift thickness is greater than specified
- o earthfill is at improper and/or variable moisture content
- o less than specified number of roller coverages are made
- o dirt-clogged rollers are used to compact the material
- o rollers may not have used optimum ballast
- o fill materials differ substantially from those specified
- o the degree of compaction is doubtful
- o directed by the Owner or the CQA Monitor

During construction, the frequency of testing may also be increased in the following situations:

- o adverse weather conditions
- o breakdown of equipment
- o at the start and finish of grading
- o material fails to meet specifications
- o the work area is reduced

4.7 Clay Liner Perforations

Perforations that must be filled shall include, but not be limited to, the following:

- o nuclear density test probe locations
- o permeability sampling locations
- o test pit locations

All clay liner perforations shall be made in accordance with the testing methods and frequencies identified in Tables 2 and 3. Construction permeability samples shall be taken such that the sample tube is inserted into the liner normal (perpendicular) to the plane of the constructed surface.

Unless otherwise noted in the project specifications, or as directed by the Owner or his representative, all perforations of the clay liner by probe or sample tube shall be backfilled with a soil-bentonite mixture. The mixture will be compacted in-place with a tamping rod, Modified or Standard Proctor hammer as specified, or hand tamper, depending on the size of the perforation. Test pit excavations shall be backfilled with the same material and using the same procedures as required for the material being tested or examined.

4.8 Deficiencies

If a defect is discovered in the earthwork product, the CQA Monitor shall immediately determine the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the CQA Monitor shall determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the CQA Monitor deems appropriate. If the defect is related to adverse site conditions, such as overly wet soils or surface desiccation, the CQA Monitor shall define the limits and nature of the defect.

4.8.1 Notification

After determining the extent and nature of a defect, the CQA Monitor shall notify the Owner and Earthwork Contractor and schedule appropriate retests when the work deficiency is to be corrected.

4.8.2 Repairs and Retesting

The Earthwork Contractor shall correct the deficiency to the satisfaction of the CQA Monitor. If a project specification criteria cannot be met, or unusual weather conditions hinder work, then the CQA Monitor shall develop and present to the Owner suggested solutions for his approval.

All retests by the CQA Monitor must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Monitor shall also verify that all installation requirements are met and that all submittals are provided (a checklist for this purpose is attached in Appendix A).

5. DOCUMENTATION

An effective construction quality assurance plan depends largely on recognition of all construction activities that should be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant shall document that all quality assurance requirements have been addressed and satisfied. The checklist attached in Appendix A may be used in this documentation, to remind the CQA Monitor of the factors to be monitored or tested.

The CQA Monitor shall provide the Project Manager with signed descriptive remarks, data sheets, and checklists to verify that all monitoring activities have been carried out. The CQA Monitor shall also maintain at the job site a complete file of plans and specifications, a CQA/QC manual, checklists, test procedures, daily logs, and other pertinent documents.

5.1 Daily Recordkeeping

Standard reporting procedures will include preparation of a daily log which, at a minimum, shall consist of: (a) field notes; including memoranda of meetings and/or discussions with the Earthwork Contractor, (b) observation and testing data sheets, and (c) construction problem and solution data sheets. This information will be regularly submitted to and reviewed by the Project Manager. Sample forms are included in Appendix D.

5.1.1 Memorandum of Discussion with Earthwork Contractor or Subcontractors

A memorandum will be prepared each day, summarizing discussions between the CQA Monitor and Earthwork Contractor. At a minimum, the memorandum will include the following information:

4.8.1 Notification

After determining the extent and nature of a defect, the CQA Monitor shall notify the Owner and Earthwork Contractor and schedule appropriate retests when the work deficiency is to be corrected.

4.8.2 Repairs and Retesting

The Earthwork Contractor shall correct the deficiency to the satisfaction of the CQA Monitor. If a project specification criteria cannot be met, or unusual weather conditions hinder work, then the CQA Monitor shall develop and present to the Owner suggested solutions for his approval.

All retests by the CQA Monitor must verify that the defect has been corrected before any additional work is performed by the Contractor in the area of the deficiency. The CQA Monitor shall also verify that all installation requirements are met and that all submittals are provided (a checklist for this purpose is attached in Appendix A).

5. DOCUMENTATION

An effective construction quality assurance plan depends largely on recognition of all construction activities that should be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Consultant shall document that all quality assurance requirements have been addressed and satisfied. The checklist attached in Appendix A may be used in this documentation, to remind the CQA Monitor of the factors to be monitored or tested.

The CQA Monitor shall provide the Project Manager with signed descriptive remarks, data sheets, and checklists to verify that all monitoring activities have been carried out. The CQA Monitor shall also maintain at the job site a complete file of plans and specifications, a CQA/QC manual, checklists, test procedures, daily logs, and other pertinent documents.

5.1 Daily Recordkeeping

Standard reporting procedures will include preparation of a daily log which, at a minimum, shall consist of: (a) field notes; including memoranda of meetings and/or discussions with the Earthwork Contractor, (b) observation and testing data sheets, and (c) construction problem and solution data sheets. This information will be regularly submitted to and reviewed by the Project Manager. Sample forms are included in Appendix D.

5.1.1 Memorandum of Discussion with Earthwork Contractor or Subcontractors

A memorandum will be prepared each day, summarizing discussions between the CQA Monitor and Earthwork Contractor. At a minimum, the memorandum will include the following information:

- o date, project name, location, and other identification
- o name of parties to discussion
- o relevant subject matter or issues
- o activities planned
- o constraints or suggestions
- o schedule
- o signature of the CQA Engineer and/or CQA Monitor

5.1.2 Observation and Testing Data Sheets

Observation and testing data sheets will be prepared daily. At a minimum, these data sheets will include the following information:

- o an identifying sheet number for cross referencing and document control
- o date, project name, location, and other identification
- o data on weather conditions
- o a reduced-scale Site Plan showing all proposed work areas and test locations
- o descriptions and locations of ongoing construction
- o equipment and personnel in each work area, including subcontractors
- o descriptions and specific locations of areas, or units, of work being tested and/or observed and documented (identified by lift and location)
- o locations where tests and samples were taken
- o a summary of test results
- o calibrations or recalibrations of test equipment, and actions taken as result of recalibration
- o off-site materials received, including quality verification documentation

- o decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality
- o the CQA Engineer and/or CQA Monitor signature

Items above should be formulated into data sheets so that none are overlooked. Sample data sheets are included in Appendix D.

5.2 Construction Problem and Solution Data Sheets

Sheets describing special construction situations shall be cross-referenced with specific observation and testing data sheets, and must include the following information, where available:

- o an identifying sheet number for cross-referencing and document control
- o a detailed description of the situation or deficiency
- o the location and probable cause of the situation or deficiency
- o how and when the situation or deficiency was found or located
- o documentation of the response to the situation or deficiency
- o final results of any responses
- o any measures taken to prevent a similar situation from occurring in the future
- o the signature of the CQA Engineer and/or CQA Monitor and signature indicating concurrence by the Project Manager

The Project Manager shall be made aware of any significant recurring non-conformance with specifications. The Project Manager shall then determine their cause and recommend appropriate changes in procedures or specifications. When this type of evaluation is made, the results must be documented, and any revision to procedures or specifications shall be approved by the Owner and Design Engineer.

A summary of all supporting data sheets, along with final testing results and the CQA Engineer's approval of the work, shall be required upon completion of construction.

5.3 Photographic Reporting Data Sheets

Photographic reporting data sheets, where used, shall be cross-referenced with observation and testing data sheet(s) and/or construction problem and solution data sheet(s).

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. The basic file will contain color prints; negatives will also be stored in a separate file in chronological order. These records shall be presented to the Project Manager upon completion of the project.

5.4 Design and/or Specifications Changes

Design and/or specifications changes may be required during construction. In such cases, the CQA Engineer shall notify the Project Manager and Design Engineer.

Design and/or specifications changes shall be made only with written agreement of the Project Manager and the Design Engineer, and shall take the form of an addendum to the specifications or Construction Quality Assurance Manual.

5.5 Progress Reports

The CQA Monitor shall prepare a summary progress report each week, or at time intervals established at the pre-construction meeting. As a minimum, this report shall include the following information:

- a unique identifying sheet number for cross-referencing and document control
- the date, project name, location, and other information
- a summary of work activities during progress reporting period
- a summary of construction situations, deficiencies, and/or defects occurring during progress reporting period
- a summary of test results, failures and retests
- the signature of the CQA Monitor

5.6 Certification and Summary Report

At the completion of the work, the CQA Engineer shall submit to the Project Manager a final certification and summary report. This report shall certify that the work has been performed in compliance with the plans and specifications, and physical sampling and testing, except as properly authorized and implemented, and that the summary document provides the necessary supporting information.

At a minimum, this report shall include (a) summaries of all construction activities, (b) observation and testing data sheets including sample location plans, (c) construction problems and solutions data sheets, (d) changes from design and material specifications, (e) as-built drawings, and (f) certification statement sealed and signed by a registered Professional Engineer. The as-built drawings shall include scale drawings depicting the location of the construction and details pertaining to the extent of construction (depths, plan dimensions, elevations, soil component thicknesses, etc.). All surveying and base maps required for development of the as-built drawings shall be done by a qualified land surveyor. This document shall be prepared by the CQA Engineer and included as part of the CQA plan documentation.

5.7 Storage of Records

All handwritten data sheet originals, especially those containing signatures, should be stored by the Project Manager in a safe repository on site. Other reports may be stored by any standard method which will allow for easy access.

Table 1

PRE-CONSTRUCTION TESTING FREQUENCY FOR MATERIAL EVALUATION
FOR SOIL COMPONENTS OF
LINING AND FINAL COVER SYSTEMS

Test and ASTM No.	Subgrade	General Earthfill	Clay Liner/Cover Stockpile	Sand Stockpile	Gravel Stockpile
Moisture Content (D2216)	--	--	1 per 20,000 cu yd*	1 per source**	1 per source**
Particle Size (Clays-D1140 other-D422)	--	--	1 per 20,000 cu yd*	1 per source**	1 per source**
Atterberg Limits (D4318)	--	1 per 20,000 cu yd*	1 per 20,000 cu yd*	--	--
Compaction (D1557) or D698)	1 per 20,000 cu yd*	1 per 20,000 cu yd*	1 per 20,000 cu yd*	--	--
Permeability (D2434 or Method in Appendix E)	--	--	1 per 20,000 cu yd per material*	1 per source	1 per source

* Minimum one test per material type.

** In addition to quarry certification.

Table 2

CONSTRUCTION TESTING FREQUENCY FOR MATERIAL EVALUATION
FOR SOIL COMPONENTS OF
LINING AND FINAL COVER SYSTEMS

Test and ASTM No.	General Earthfill	Clay Liner/Cover in place	Sand in place	Gravel in place	Cover Over Geomembrane	Vegetative Cover
Moisture Content (D2216)	--	1 per 1,000 cu yd**	1 per 10,000 sq ft*	1 per 10,000 sq ft*	--	--
Particle Size (Clays-D1140 other-D422)	--	1 per 1,000 cu yd*	1 per 10,000 sf* sq ft*	1 per 10,000 sq ft*	1 per 10,000 cu yd**	1 per 5,000 cy** cu yd**
Atterberg Limits (D4318)	1 per 10,000 cu yd**	1 per 5,000 cu yd*	--	--	--	--
Compaction (D1557 or D698)	As necessary	1 per 5,000 cu yd or changes	--	--	As necessary	--
Laboratory Permeability	--	1 per 5,000 cu yd	--	--	--	--

* minimum two tests per layer per subcell

** minimum one test per source

A subcell is a unit within a landfill or surface impoundment which is physically separated from other portions of the facility by an intermediate berm.

Table 3

CONSTRUCTION TESTING FREQUENCY FOR QUALITY EVALUATION
FOR SOIL COMPONENTS OF
LINING AND FINAL COVER SYSTEMS

Test	Subgrade	General Earthfill	Clay Liner/Cover Material	Sand	Drainage Material Gravel	Protective Cover over Geomembrane
Field Moisture Content/Density	1 per 10,000 sq ft or minimum of six per lift whichever is greater	1 per 10,000 sq ft or minimum of six per lift whichever is greater	1 per 10,000 sq ft or minimum of six per lift whichever is greater	--	--	1 per 10,000 sq ft or minimum of six per lift whichever is greater
Penetrometer or Torvane Shear	Weak or suspect areas	--	--	--	--	--
Surveys* As-Built Condition Elevation Monitoring	All appurtenant components 50 feet center to center or minimum 6 points per grade at least at the following locations: - base of excavation - top of first clay lift for each layer - top compacted clay layers - top of all collection systems - base and top of all sumps and drains - as directed by the Owner or his representative					
Density Test and Permeability Sample Locations	As selected by the Inspector					
Layer Bonding Compacted Clay	As noted in Test Fill description (see Appendix B)					

* To be performed by a qualified land surveyor.

Appendix A
CONSTRUCTION QUALITY ASSURANCE CHECKLIST

Appendix A

CONSTRUCTION QUALITY ASSURANCE CHECKLIST

I. Submittal of Qualifications (2.3)

A. Earthwork Contractor (2.3.1)

1. Demonstration of bonding capability and list of outstanding contracts ____

2. A list of five comparable projects ____

a. name of facility, location, and date of installation ____

b. name of project manager or contact person for installation ____

c. description and purpose of installation and definition of contractor's scope ____

3. A list of readily available equipment ____

B. CQA Consultant (2.3.2)

1. Corporate information ____

a. corporate history ____

b. proof of insurance

1) professional liability ____

2) "umbrella" coverage ____

3) other coverages required by state and local statutes or proposed contractual agreements ____

2. Inspection Capabilities

a. summary of firms experience with observation and testing, especially soil components for waste facilities ____

b. summary of firms experience in CQA/QC (emphasis on soil components) ____

3. Personnel

a. resumes of personnel to be involved in the project ____

b. supervising engineer must have proof of engineering degree and/or professional engineering registration in project state ____

c. specific experience with soil components of inspecting personnel ____

II. Meetings (3)

A. Resolution meeting (with Design Engineer, Owner, Project Manager, and CQA Monitor present) (3.1)

1. Provide all parties with relevant documents ____

2. Review plans and specifications ____

3. Make modifications to CQA plan ____

4. Review of the CQA plan and quality control procedures ____

5. Review and assign responsibilities to parties ____

6. Establish procedures for documentation and reporting information ____

7. Establish methods for distribution and storage of documents and reports ____

8. Prepare a time schedule for operations ____

9. Establish work area security and safety protocol ____

10. Discuss and select earthwork contractors to be asked to bid ____

11. Review special permit conditions and/or state and federal requirements ____

12. Select testing equipment as well as protocol for testing and placement of soil materials ____

13. Meeting documented by CQA Monitor or designate and minutes transmitted to all parties ____

B. Pre-Construction Meeting (with Earthwork Contractor, CQA Monitor, and Project Manager present) (3.2)

1. Discuss modifications to CQA plan ____
2. Review special permits and state and federal requirements ____
3. Review responsibilities of each party ____
4. Review lines of authority and communication ____
5. Review procedures for documentation and reporting information ____
6. Review distribution and storage of documents and reports ____
7. Establish protocol for testing ____
8. Establish protocol for handling construction deficiencies ____
9. Establish protocol for repairs and retesting ____
10. Conduct site-walk ____
    a. discuss work plans ____
    b. inspect material handling, borrow, and stockpile locations ____
11. Review a time schedule for all operations ____
12. Review work area security and safety protocol ____
13. Discuss and establish procedures for material processing ____
14. Establish procedures for control of water and general materials protection and housekeeping ____
15. Review health and safety requirements ____
16. Meeting documented by CQA Monitor or designate and minutes transmitted to all parties prior to start of construction ____

C. Progress Meetings with Earthwork Contractor and CQA Monitor (3.3)

1. Review work activity and location for the day ____

2. Discuss personnel and equipment for the assignment of the day ____

3. Review previous day's activities and accomplishments ____

4. Review work schedule ____

5. Discuss possible problems ____

6. Review new test data ____

7. Meeting documented by CQA Monitor ____

D. Problem or Work Deficiency Meeting (with Earthwork Contractor, Owner, and CQA Monitor present) (3.4)

1. Define and discuss the problem or deficiency ____

2. Review alternative solutions ____

3. Implement action plan ____

4. Meeting documented by CQA Monitor ____

III. Earth Materials Construction Quality Assurance (4)

A. Material Evaluation (4.2)

1. Laboratory Soil Tests (4.2.2)

a. laboratory determination of water moisture content of soil, rock, and soil aggregate mixtures (ASTM D2216-80) ____

b. particle-size analysis of soils; amount of material finer than No. 200 sieve (ASTM D422-63) and (ASTM D1140-54) ____

c. laboratory determination of liquid limit and plasticity index of soil (ASTM D4318-83) ____

d. shrinkage factors of the soils (ASTM D427-83) ____

e. specific gravity of soils (ASTM D854-83) ____

2. Soils Selection Criteria (4.2.3)

a. general earthfill shall consist of material taken from on-site or approved off-site excavations or stockpiles and shall meet the requirement of Section 4.2.3.1 ____

b. clay liner/cover material (4.2.3.2) ____

1) natural soil (4.2.3.2.1) ____

a) shall consist of clean, select material free of organics, trash, excess silt, or other deleterious matter ____

b) shall be classified as CL or CH ____

c) shall not be organic soil ____

d) may be sand and silt soils (SC, ML, MH) ____

e) shall have recompacted coefficient of permeability equal to or less than 1×10^{-7} cm/sec ____

2) admix material (4.2.3.2.2)

a) admixing of soils to lower permeability to 1×10^{-7} performed with written approval of Project Manager ____

b) manufacture of admix conducted in accordance with Section 4.2.3.2.2 ____

c) admix material shall meet with the approval of the Inspector/Engineer ____

c. drainage materials (4.2.3.3)

1) shall consist of clean sands and/or gravels or other permeable material (SW, SP, GW, or GP) ____

2) shall be free from contamination ____

3) shall contain less than 5 percent (dry weight) material that passes the No. 200 sieve and with 100 percent by weight passing the 3-inch sieve ____

4) gravels for pipe trenches shall be GW or GP ____

5) gravels for pipe trenches contain less than 5 percent fines and be of a gradation whereby 95 percent of the material is larger than the perforations at the drainage pipe ____

6) drainage layers shall have a permeability greater than or equal to 1×10^{-2} cm/sec ____

d. protective cover over membrane (2.4.3.5)

1) must be fine-grained earthfill with maximum particle size of 1/4 inch ____

2) if protective geotextile used, a particle of 1 inch is permissible ____

e. vegetative cover material (4.2.3.5)

1) shall be topsoil material and/or soil capable of providing for establishment of surficial grasses ____

3. Test Fill (4.2.4)

a. test fill shall be used to evaluate

1) material handling and placement requirements ____

2) compaction equipment and procedures ____

3) number of coverages needed to achieve required results ____

4) permeability samples ____

b. test fill dimensions a minimum of 20 feet by 60 feet ____

c. test fill shall be constructed using the same equipment to be used on the project ____

d. test fill observed and tested by CQA Monitor ____

B. Construction Quality Evaluation (4.3)

1. Inspection of the Work (4.3.1)

a. inspection of the water content and other physical properties ____

b. inspection of thickness of lifts, loosely placed and compacted ____

c. inspection of action of heavy equipment on the construction surface ____

d. inspection of number of coverages for each lift ____

2. Evaluation of Layer Bonding (4.3.2)

a. layer bonding can be evaluated by observing test pits ____

b. test pits excavated in a manner acceptable to the CQA Monitor ____

c. each test pit shall be excavated to 1 foot in depth ____

d. test pits shall be backfilled and compacted in accordance with the specifications using a hand compactor to the satisfaction of the CQA Monitor (or Owner or his representative) ____

3. Laboratory and Field Tests (4.3.3)

a. compaction test (5.5-pound hammer, 12-inch drop) (ASTM D698-78) ____

b. compaction test (10-pound hammer, 18-inch drop) (ASTM D1557-78) ____

c. liquid limit, plastic limit, and plasticity index (ASTM D4318-83) ____

d. sieve analysis (passing No. 200 sieve) (ASTM D422-63 and ASTM D1140-54) ____

e. strength test; pocket penetration ____

f. strength test; Torvane shear ____

g. field moisture/density determination: drive cylinder (ASTM D2937-83) ____

h. field moisture/density determination: nuclear methods (ASTM D2922-81 and ASTM D3017-78) ____

i. field moisture/density determination: rubber balloon (ASTM D2167-66) ____

j. field moisture/density determination: sand-cone method (ASTM D1556-82) ____

Note: minimum of 1 sand-cone test per 20 nuclear tests (1 per day)

k. failing area shall be reworked ____

4. Subgrade (4.3.4)

a. subgrade soil tested to confirm proper soil characteristics achieved ____

b. CQA Monitor shall observe subgrade during proof-rolling ____

c. CQA Monitor shall perform pocket penetrometer or Torvane sheer test in suspect soil areas ____

d. optional tests ____

1) laboratory test: compaction test ____

2) field test: moisture/density ____

3) field test: pocket penetrometer ____

C. Hydraulic Conductivity Evaluations (4.4)

1. Laboratory tests shall be performed to assess hydraulic conductivity of materials during pre-construction (one of the following):

a. permeability of granular soil (constant head test) (ASTM D2434-68) ____

b. permeability (back pressure saturated) (see Appendix E) ____

c. Atterberg Limits ____

d. particle size analysis ____

D. Special Testing (4.5) (as deemed necessary by the Owner or his representative)

1. Compressive strength, unconfined cohesive soils (ASTM D2166-66) ____

2. One-dimensional consolidation properties of soils (ASTM D2435-80) ____

3. Direct shear (consolidated, drained) ASTM 3080-72) ____

4. Shear, triaxal compression ____

   a. consolidated drained (CD) (see U.S. Army Corps of Engineers EM 1110-2-1906 or Lambe, 1951) ____

   b. consolidated undrained (CU) (see U.S. Army Corps of Engineers EM 1110-2-1906 or Lambe, 1951) ____

   c. unconsolidated undrained (UU) ASTM D2850-82 ____

E. Quality Control Testing Frequency (4.6)
   see Tables 1, 2, and 3 of the manual)

F. Clay Liner Perforations (4.7)

1. Construction permeability samples taken such that the sample tube is inserted into the liner normal to the plane of the constructed surface ____

2. All perforations shall be backfilled with soil-bentonite mixture ____

3. Backfill mixture compacted in-place using appropriate method ____

4. Perforation requiring filling include; density probe, permeability sample locations, and test pits ____

G. Deficiencies (4.8)

1. CQA Monitor shall determine the extent and nature of the defect immediately upon discovery ____

2. CQA Monitor shall notify Owner and Contractor of defect, and schedule retests for corrected work ____

3. Corrections shall be verified by retest performed by CQA Monitor ____

4. CQA Monitor shall verify that all installation requirements are met and all submittals are provided ____

IV. Documentation (5)

A. Daily Recordkeeping (completed by CQA Monitor) (5.1)

1. Daily memorandum of discussion with Earthwork Contractor (fill in appropriate form) ____

2. Observation and testing data sheets (fill in appropriate form) ____

B. Construction Problem and Solution Data Sheets (5.2) to Include:

1. A unique identifying sheet number ____

2. A detailed description of the situation or deficiency ____

3. Location and probable cause or situation or deficiency ____

4. How and when situation or deficiency was discovered ____

5. Documentation of the response to the situation or deficiency ____

6. Final result of the response ____

7. Measure undertaken to avoid or prevent similar future occurrences ____

8. Signature of the CQA Monitor and Project Manager ____

9. Summary of all supporting data and test sheets required upon completion of construction ____

C. Photographic Reporting Data Sheet (5.3) ____

D. Design and/or Specification Changes (5.4)

1. CQA Monitor shall inform the Project Manager and Design Engineer of any design and/or specification changes ____

2. Design and/or specification changes shall be made only with written agreement of the Project Manager and the Design Engineer. This change shall take the form of an amendment to the specification or Construction Quality Assurance Manual. ____

E. Progress Reports (5.5)

1. The CQA Monitor shall prepare a summary progress report weekly, or at a frequency established at the pre-construction meeting ____

2. The Progress Report will include:

   a. a unique identifying sheet number ____

   b. the date, project name, location, and other information ____

   c. a summary of work activities during progress reporting periods ____

   d. a summary of construction situations, deficiencies and/or defects occurring during progress reporting period ____

   e. a summary of test results, failures, and retests ____

   f. the signature of the CQA Monitor ____

F. Certification and Summary Report (5.6)

1. The CQA Consultant shall submit to the Project Manager a final certification and summary report that includes:

   a. summaries of construction activities ____

   b. observation and testing data sheets with test location plans ____

   c. construction problems and solutions data sheets ____

   d. changes from design and material specifications ____

   e. as-built drawings, including:

      1) scale drawings with locations and extent of construction ____

      2) surveying and base maps required done by qualified land surveyor ____

      3) as-built document prepared by the CQA Engineer and included in the CQA plan documentation ____

V. Testing Frequency

A. Pre-Construction Testing Frequency for Material Evaluation

1. Subgrade

a. compaction test (ASTM D1557 or ASTM D698) 1 per 20,000 cu yd ____

2. General Earthfill

a. Atterberg Limits (ASTM D4318) 1 per 20,000 cu yd ____

b. compaction test (ASTM D1557 or ASTM D698) 1 per 20,000 cu yd ____

3. Clay Liner/Cover Stockpile

a. moisture content (ASTM D2216) 1 per 20,000 cu yd ____

b. particle size - (clays ASTM D1140, other ASTM D422) 1 per 20,000 cu yd ____

c. Atterberg Limits - (ASTM D4318) 1 per 20,000 cu yd ____

d. compaction test - (ASTM D1557 or D698) 1 per 20,000 cu yd ____

e. permeability - 1 per 20,000 cu yd per material ____

4. Sand Stockpile

a. moisture content - ASTM D2216 1 per source ____

b. particle size - (clays ASTM D1140, other ASTM D422) 1 per source ____

c. permeability - 1 per source ____

5. Gravel Stockpile

a. moisture content - (ASTM D2216) 1 per source ____

b. particle size - (clays ASTM D1140, other ASTM D422) 1 per source ____

c. permeability - 1 per source ____

(NOTE: See Table 1 of Construction Quality Assurance Manual)

B. Construction Testing Frequency for Material Evaluation

1. General Earthfill

   a. Atterberg Limits - (ASTM D4318) 1 per 10,000 cu yd ____

   b. compaction test - (ASTM D1557 or ASTM D698) as necessary ____

2. Clay Liner/Cover in Place

   a. moisture content - (ASTM D2216) 1 per 1,000 cu yd ____

   b. particle size - (clays ASTM D1140, other ASTM D422) 1 per 1,000 cu yd ____

   c. Atterberg Limits - (ASTM D4318) 1 per 5,000 cu yd ____

   d. compaction test - (ASTM D1557 or D698) 1 per 5,000 cu yd or changes ____

   e. laboratory permeability - 1 per 5,000 cu yd ____

3. Sand In Place

   a. moisture content - (ASTM D2216) 1 per 10,000 sq ft ____

   b. particle size - (clays ASTM D1140, others ASTM D422) 1 per 10,000 sq ft ____

4. Gravel in Place

   a. moisture content - (ASTM D2216) 1 per 10,000 sq ft ____

   b. particle size - (clays ASTM D1140, other ASTM D422) 1 per 10,000 sq ft ____

5. Cover over Geomembrane

   a. particle size - (clays ASTM D1140, other ASTM D422) 1 per 5,000 cu yd ____

6. Vegetative Cover

   a. particle size - (clays ASTM D1140, other ASTM D422) 1 per 5,000 cu yd ____

(NOTE: See Table 2 of Construction Quality Assurance Manual)

C. Construction Testing Frequency for Construction Quality Evaluation

1. Subgrade

   a. field moisture/density - 1 per 10,000 sq ft ____

   b. penetrometer or Torvane shear - weak or suspect areas ____

2. General Earthfill

   a. field moisture/density - 1 per 10,000 sq ft ____

3. Clay Liner/Cover Material

   a. field moisture/density - 1 per 10,000 sq ft ____

4. Protective Cover over Geomembrane

   a. field moisture/density - 1 per 10,000 sq ft ____

(NOTE: See Table 3 of Construction Quality Assurance Manual)

Appendix B
TEST FILL PROGRAM

Appendix B
TEST FILL PROGRAM

1.0 PURPOSE AND SCOPE

The purpose of the test fill is to establish a sequential and logical approach for the development of placement and compaction procedures to be used during construction of cohesive soil liners as an indicator that the soil liners are constructed in a way that meets design performance specifications. The test fill program will allow the Contractor, the Design Engineer, and the Construction Quality Assurance (CQA) Engineer to identify appropriate placement and compaction procedures by establishing relationships between various compaction parameters, density, water content, Atterberg limits, particle size distribution, and permeability of the fill.

Once the construction procedures have been established by the test fill program, the Contractor and the CQA Engineer will monitor the cohesive soil liner construction procedures as an indicator that the design performance specifications are being achieved. Test fill construction procedures will include measuring lift thickness, counting the number of compactor coverages, and performing in-place density and moisture content tests to verify that the specified degree of compaction is achieved.

The test fill will be constructed in uniform horizontal lifts of uniform thicknesses.

This test fill program documents the requirements for constructing the test fill (Figure 1). The test fill program will include:

- o subgrade preparation
- o construction of a 3-foot-thick test fill

- o inspection and testing of the test fill
- o sampling of portions of the test fill

The test fill program described in this appendix may be modified based on site specific design and construction considerations.

Feasibility testing of clay sources will have been performed before the start of the test fill. These tests should provide the basic relationship of permeability with varying density and moisture content. A typical representation of compaction and laboratory permeability test results for one clay source is shown on Figure 2.

2.0 CONSTRUCTION EQUIPMENT

The equipment to be used for the test fill shall be proposed by the Contractor, and approved by the CQA Engineer and Project Manager.

3.0 TEST FILL MATERIAL

Test fill material shall be approved by the CQA Engineer. The Material shall be an inorganic cohesive soil with a plasticity index (PI) ranging between 10 and 40; at least 50 percent of the soil shall pass the No. 200 sieve. As approved by the CQA Engineer, small quantities of fill with PI greater than 40 may be allowed if such materials are thoroughly mixed with other less plastic soils. Other materials may be considered based upon laboratory testing and upon approval of the Project Manager. The maximum particle size shall be 4 inches.

No frozen material shall be used, and in-place material that becomes frozen prior to completion of operations shall be removed.

4.0 TEST FILL CONSTRUCTION

4.1 Subgrade Preparation

The area within the limits of the test fill shall be cleared and grubbed of all trees, debris, brushes, stumps, roots, trash, and any other vegetation or objectionable material. Following clearing and grubbing, the area shall be stripped of topsoil. Topsoil shall be stockpiled in an area designated by the Project Manager.

The surface of the subgrade shall be proof-rolled so as to be free of soft zones, irregularities, loose earth, and abrupt changes in grade. The subgrade and test fill shall be sloped at a 2 percent grade. No standing water or excessive moisture shall be allowed on the surface of the subgrade. The surface shall be inspected by the CQA Engineer prior to beginning construction of the test fill.

4.2 Configuration

The test fill shall be a rectangle approximately 60 feet long by 20 feet wide (Figure 1). The test fill shall be constructed to a thickness of 3 feet in uniform horizontal lifts. Lines and grades shall be controlled by survey.

4.3 Fill Placement

The test fill shall be constructed in uniform horizontal lifts to a total thickness of 3 feet after compaction in accordance with the procedures specified below. The procedures, which vary with the lift considered, are intended to allow determination of a relationship between soil compaction criteria, which include density and moisture content, permeability, and compaction method parameters. Compaction method parameters include: (1) compactor characteristics, (2) thickness of compacted/uncompacted layers, (3) number of compactor coverages, and (4) soil moisture content.

4.3.1 First Lift

1. The first lift of test fill material shall be placed to a thickness resulting in 6 inches after compaction.

2. Soil moisture content shall be maintained between -2 and +4 percentage points of the optimum water content determined by the CQA Engineer. The Contractor shall adjust the moisture content as necessary to obtain the specified density criteria.

3. The test fill material shall be compacted with two one-way coverages using the Contractor's proposed compaction equipment.

4. The Contractor shall permit the CQA Engineer to perform in-place density tests and collect soil samples as specified in Section 5.3.

5. Holes left in the lift shall be repaired in accordance with methods outlined in the CQA plan. The repairs shall be compacted using procedures which have been shown to meet the required moisture and density criteria.

6. The test fill material shall be compacted a second time by applying two more one-way coverages with the selected compactor.

7. Steps 4 and 5 shall be repeated. Second tests shall be taken near the original tests.

8. The test fill material shall be compacted a third time by applying two more one-way coverages with the selected compactor.

9. Steps 4 and 5 shall be repeated. Third tests shall be taken near the first and second tests.

10. Steps 8 and 9, respectively, shall be repeated and continued until specified compaction criteria are obtained as identified by the CQA Engineer.

4.3.2 Second Lift

1. The loose thickness of the second lift shall be such that the thickness of the lift will be 6 inches after compaction.

2. A competent bond with the first lift shall be achieved by the Contractor and approved by the CQA Engineer.

3. Steps 2 through 10 of Section 4.3.1 shall be repeated.

4.3.3 Remaining Lifts

1. The loose thickness of the remaining lifts shall be such that the thickness of the lifts will be 6 inches after compaction.

2. The procedures for compacting and testing the remaining lifts shall be those that have been tested and proven effective during the compaction of the second lift.

4.3.4 Final Surface Preparation

The surface of the test fill shall be rolled with a smooth steel drum or pneumatic roller so as to be free of irregularities, loose earth, and abrupt changes in grade. All stones larger than 1 inch shall be removed. Stones which are smaller than 1 inch and are judged to be detrimental to a geomembrane liner will be removed. One-half of the prepared soil surface shall be protected against drying with temporary plastic sheets. The sheets shall be placed immediately after the completion of surface preparation. Observations and documentation of desiccation cracking versus time shall be made on the uncovered section of the test fill.

5.0 INSPECTION AND TESTING

5.1 Test Fill Material

The CQA Engineer shall perform testing on the cohesive soil material prior to its use in the test fill. Testing will include at least the following:

- o soil density/moisture content relationship using the Standard Proctor compaction method (ASTM D 698-78)
- o natural water content (ASTM D 2216-80)
- o particle size distribution (ASTM D 422-63)
- o Atterberg limits (ASTM D 4318-84)
- o soil classification (ASTM D 2487-83)

5.2 Subgrade Preparation

The CQA Engineer shall observe the prepared subgrade for firmness, smoothness, and absence of abrupt changes in grade.

5.3 Test Fill Construction

5.3.1 Lift Compaction

For the first and second lifts, the CQA Engineer shall perform the following activities:

- o estimate the thickness of the loose lifts
- o count the number of compactor coverages and observe compactor coverage of the test fill (Figure 1)
- o at every two (2) coverages, perform a minimum of eight nuclear gauge in-place density and moisture readings (ASTM D 2292-81) and a minimum of two in-place density

tests using the sand-cone method (ASTM D 1556-82) to verify the nuclear gauge readings; compute degree of compaction (i.e., in-place dry density divided by the Standard Proctor maximum dry density); collect four additional soil samples for moisture content determination (ASTM D 2216-80)

- o observe the repair of holes left in the lift as a result of density testing and soil sample collection
- o continue in-place density testing and moisture content determination to enable development of a curve giving in-place dry density versus number of compactor coverages for each lift thickness (Figure 3)

For each of the remaining lifts, the CQA Engineer shall perform the following activities:

- o verify that the thickness of the loose lift does not exceed the loose thickness determined from testing of the second lift
- o count the number of compactor coverages, determined from testing of the second lift, which are necessary to achieve the specified density and observe compactor coverage of the test fill
- o perform a minimum of eight nuclear density tests and two sand-cone density tests per lift to verify the adequacy of the construction procedures previously established

The CQA Engineer shall collect a minimum of six (6) undisturbed Shelby tube samples or 8 inch x 8 inch x 6 inch undisturbed block soil samples from varying depths of the completed test fill. The samples shall be waxed or otherwise protected to retain natural moisture and tested in the laboratory for the following:

- o hydraulic conductivity (permeability) using water as the permeant
- o dry density
- o particle size distribution (ASTM D 422-63)
- o Atterberg limits (ASTM D 4318-84)

- o soil classification (ASTM D 2487-83)
- o soil moisture content (ASTM D 2216-80)

The CQA Engineer shall observe the test fill to verify the adequacy of the bonding between adjacent lifts. Such observation shall be exercised on the portion of the test fill which has been excavated to permit removal of undisturbed soil block samples and or the sand-cone density testing.

5.3.2 Final Surface Preparation

The CQA Engineer shall observe the prepared surface for firmness, smoothness, and absence of abrupt changes in grade.

5.3.3 Permeability Testing

The permeability of the test fill shall be assessed by performance of a minimum of six (6) laboratory tests on specimens trimmed from the undisturbed block or Shelby tube samples tested at a location selected by the CQA Engineer.

5.4 Test Results

The test results which will be used to verify that the specified construction procedures meet the design performance criteria shall be:

- o compaction testing (i.e., degree of compaction, in-place dry density, and moisture content)
- o results of laboratory permeability testing performed on undisturbed soil samples
- o soil index testing to evaluate material suitability

5.5 Lines and Grades

The following surfaces shall be surveyed to verify that proper thicknesses have been constructed:

- o prepared surface of the subgrade
- o final surface of the test fill

6.0 DOCUMENTATION

The CQA Engineer shall document activities associated with the construction, monitoring, and testing of the test fill. Such documentation shall include daily reports of construction activities and oral communications with the Contractor. In addition, the following shall be documented for each of the sections listed below:

6.1 Test Fill Material

The CQA Engineer shall provide a moisture-density relationship for the test fill liner material and other and other test results as specified in Section 5.1.

6.2 Test Fill Construction

6.2.1 Subgrade Preparation

The CQA Engineer shall document observations on subgrade preparation, as specified in Section 5.2.

6.2.2 Test Fill Construction

The CQA Engineer shall document activities of the test fill construction, monitoring, and testing in a test fill summary report, which shall include but not be limited to:

- record of the compactor type, configuration, and weight; for sheepsfoot compactors, record the drum diameter and length, empty and ballasted weight, length and face area of feet, and yoking arrangement, if any

- record thicknesses of lifts prior to and after compaction

- record density versus number of compactor coverages for each lift thickness, as specified in Section 5.3.1

- record the number of compactor coverages which will provide the specified degree of compaction and permeability

- record the procedure to bond lifts

- results of moisture, in-place density and degree of compaction, as specified in Section 5.3.1

- repair of holes left in the lift as a result of density testing and soil sample collection, as specified in Section 5.3.1

- results of laboratory permeability testing and other soil properties tests performed on undisturbed soil samples

- as-built drawing of the test fill and locations of all test samples for each lift

- cross-section of the test fill showing number of lifts and lift thickness

- description of actual construction procedures

- observations of test fill excavation for removal of undisturbed soil samples and observations of layer bonding, as specified in Section 5.3.1.

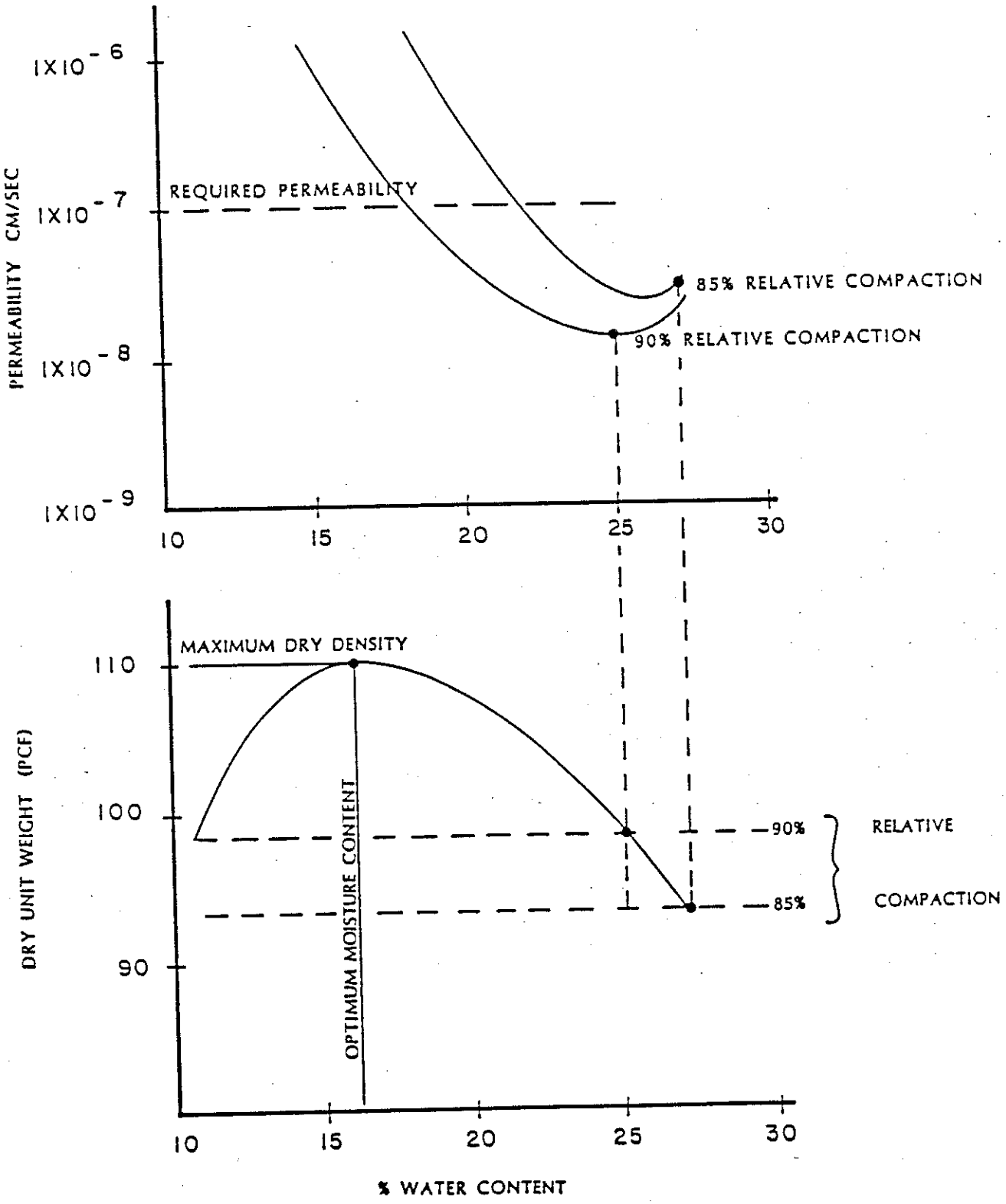
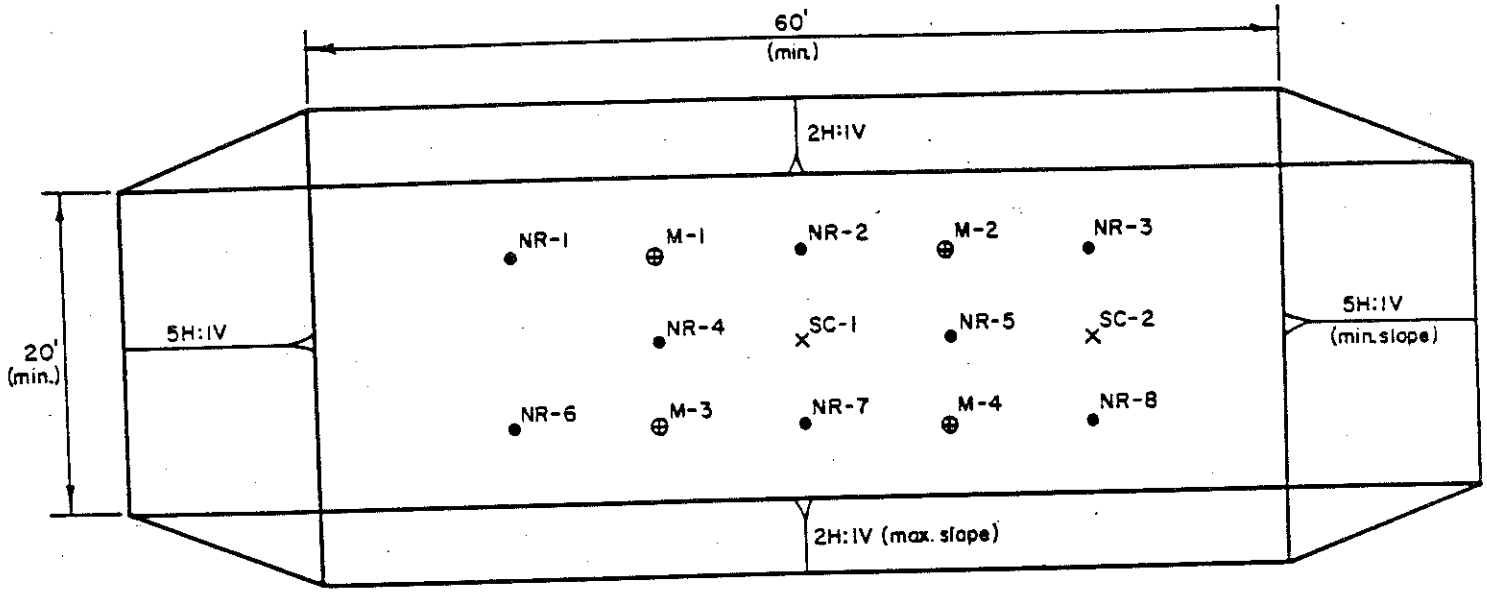


FIGURE NUMBER 2

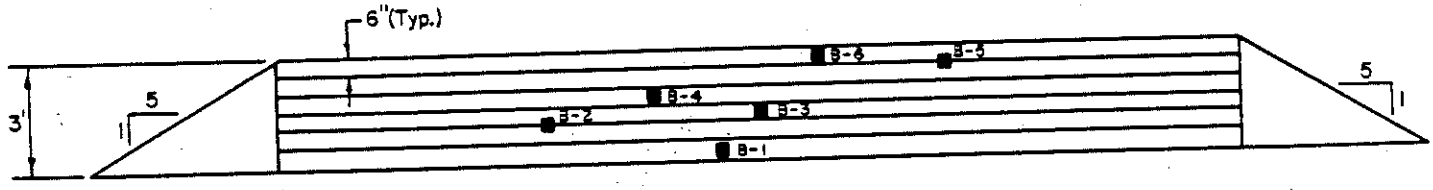
PERMEABILITY, DENSITY AND MOISTURE CONDITION RELATIONSHIP

(ILLUSTRATIVE ONLY)



LEGEND

- ●NR-1 Nuclear guage reading on density and moisture (8 min./lift)
- ×SC-1 Sand cone test (2 min./lift)
- ⊕M-1 Moisture content sample (4 min./lift)
- ■B-1 Shelby tube or block sample for laboratory testing (6 min. at varying depths throughout test fill)



NOTES

1. The configuration and location of sample selection are included as an example only and may vary from test fill to test fill.
2. Sample locations shall be selected by the CQA engineer.

FIG. 1 SUGGESTED TEST FILL CONFIGURATION

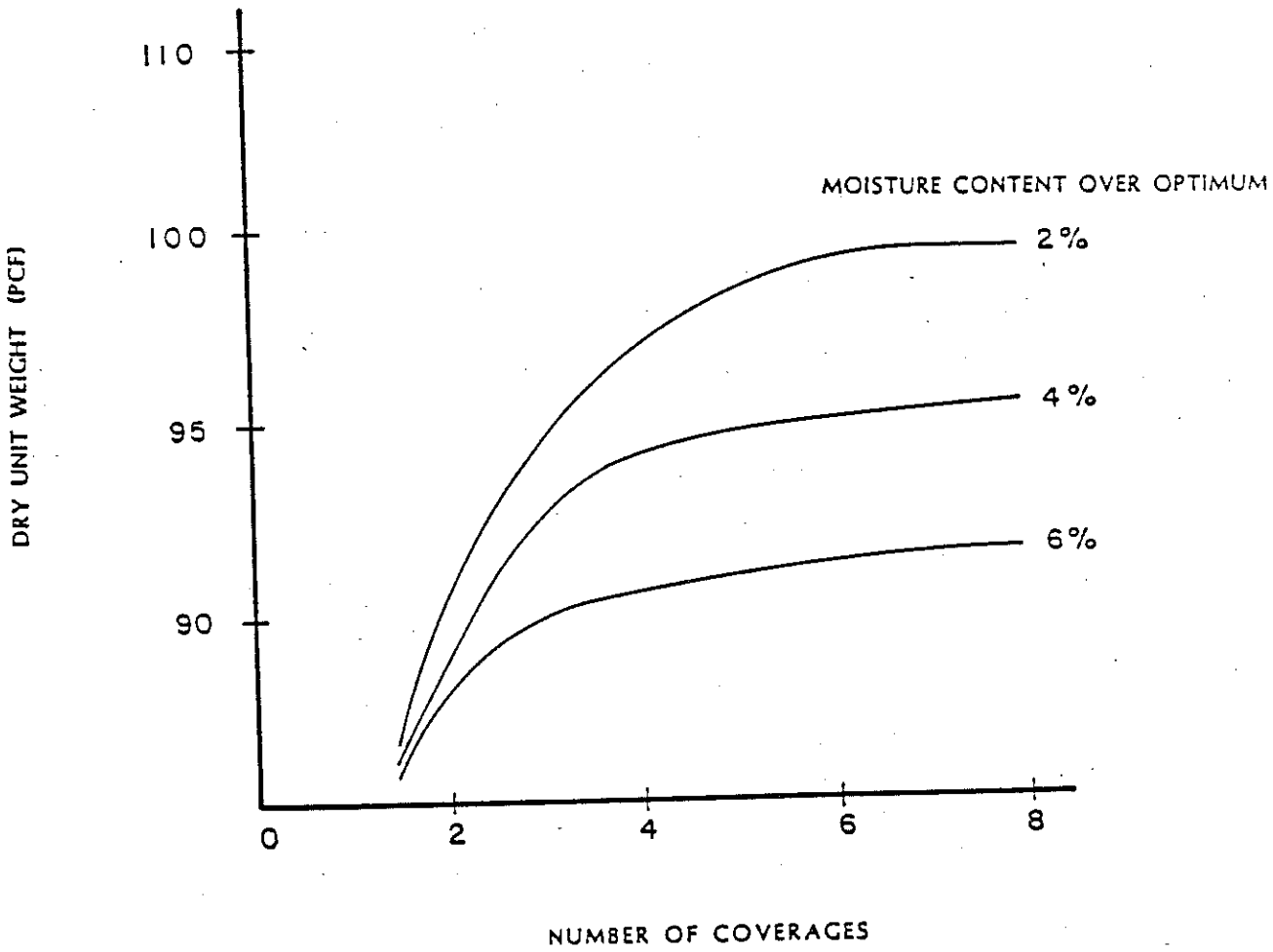


FIGURE NUMBER 3

MOISTURE/ DENSITY/ COMPACTIVE EFFORT RELATIONSHIP

Appendix C
NONBIASED SAMPLE PLANS

California Test 231
1978

FIGURE 3

NONBIASED SAMPLE PLANS

Once an area is selected on the basis of uniformity of features, randomized locations of measurement sites is required for applying statistical control procedures. The randomized sample location plans will randomly locate the approximate measurement sites. Note: The number of measurement sites must be determined after the area has been determined and before any tests performed.

PROCEDURE FOR USE OF
NONBIASED SAMPLE PLANS

1. a. Use the last digit from the first reading taken for the daily standard count to select the plan for the first area. For subsequent areas use the last digit from the second, third, fourth, and fifth readings. If six through ten areas are tested, use the second to the last digit from the first through the fifth readings taken for the daily standard count.

   b. Nuclear gages that electronically average the standard counts - Take a 1/1 minute count in the safe position at any convenient location, i.e., ground, truck bed, carry case, etc., prior to selecting the plan for an area. Use the last digit of the density reading for selecting the plan. A new count should be taken for each area.

2. Visualize the plan as a map of the area to be sampled.

3. Each dot represents a measurement site. There are 10 dots numbered from one (1) through ten (10). If you are to take a five (5) site test then use the dots numbered from one (1) through five (5). If a three site test is going to be used then use the locations of the first three dots. This procedure will be used for all tests, with number 1 dot the first site, number 2 dot the second site and so on until the desired number of sites have been used.

4. Test at the approximate locations on the grade represented by the dots on the plan. Some adjustments are necessary for irregular areas.

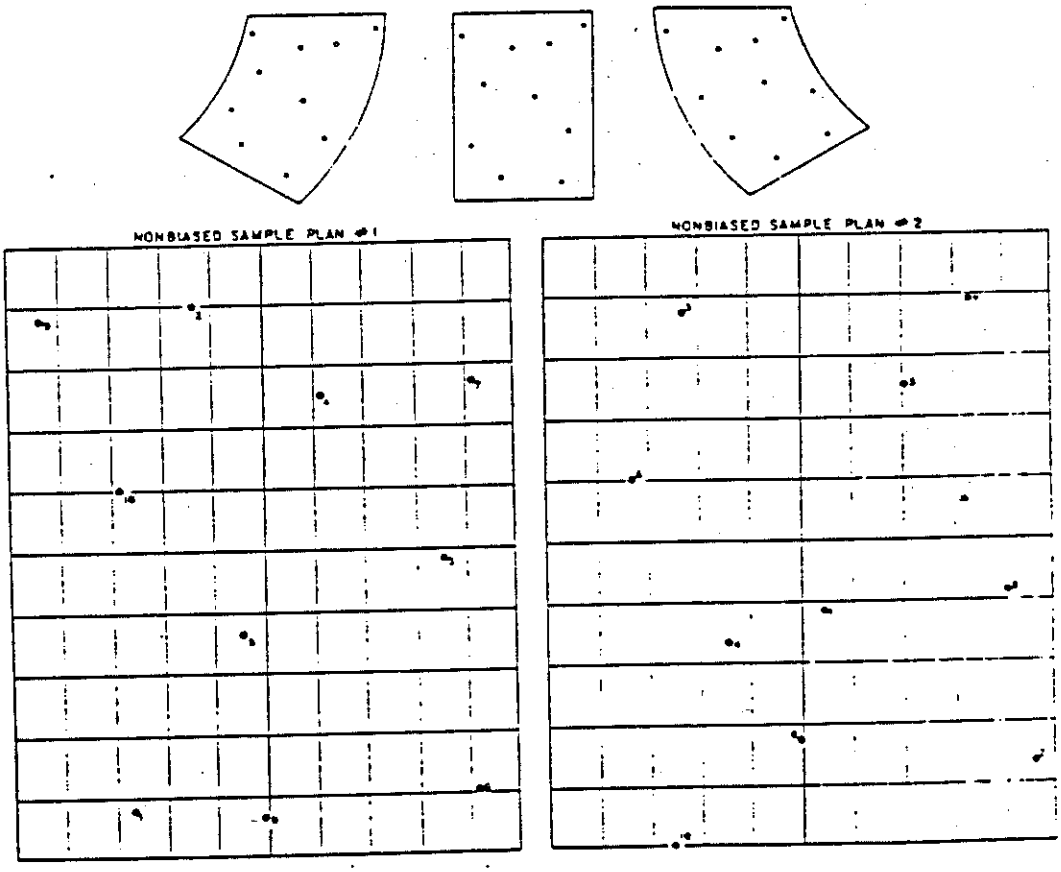


FIGURE 3

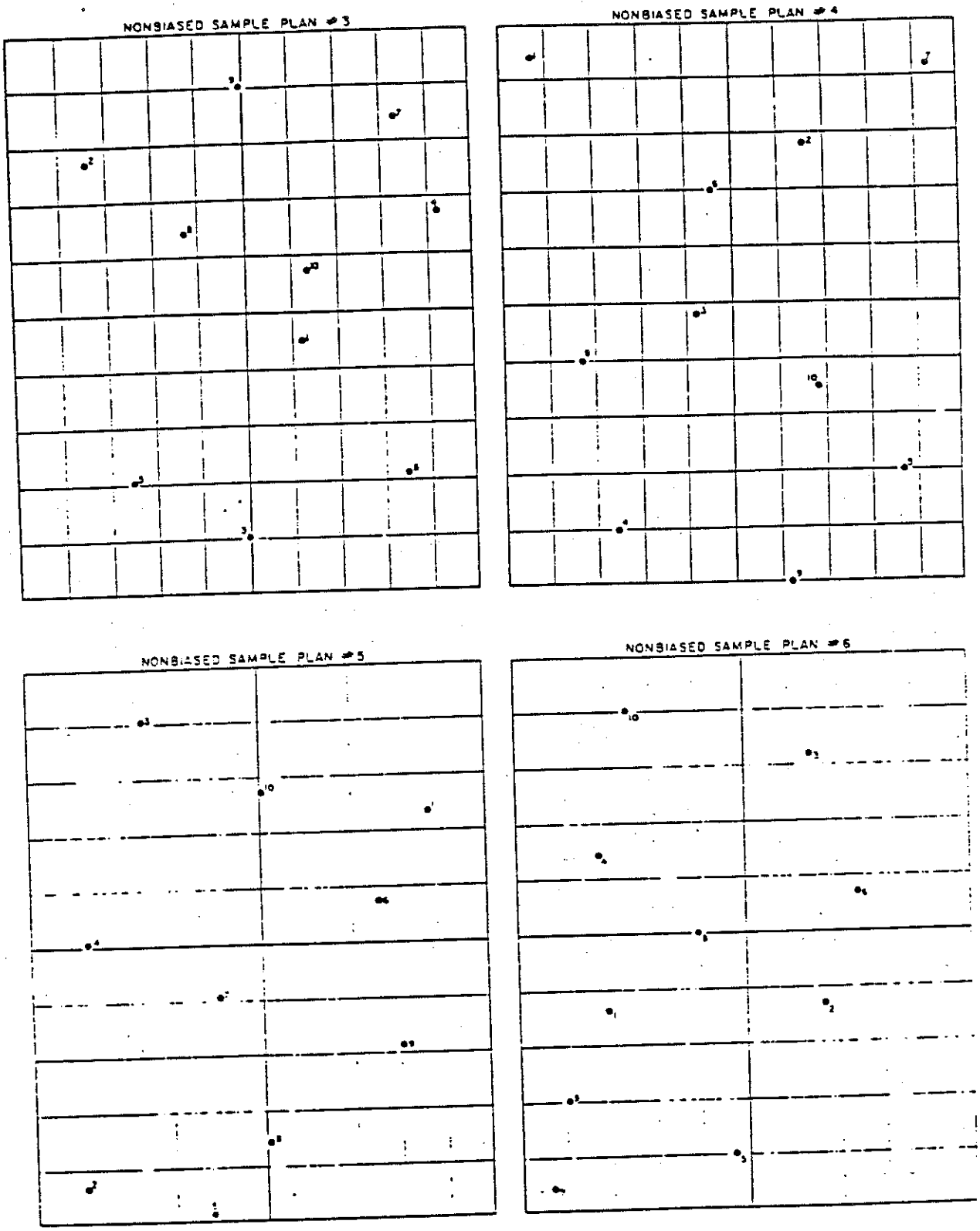


FIGURE 3 (Continued)

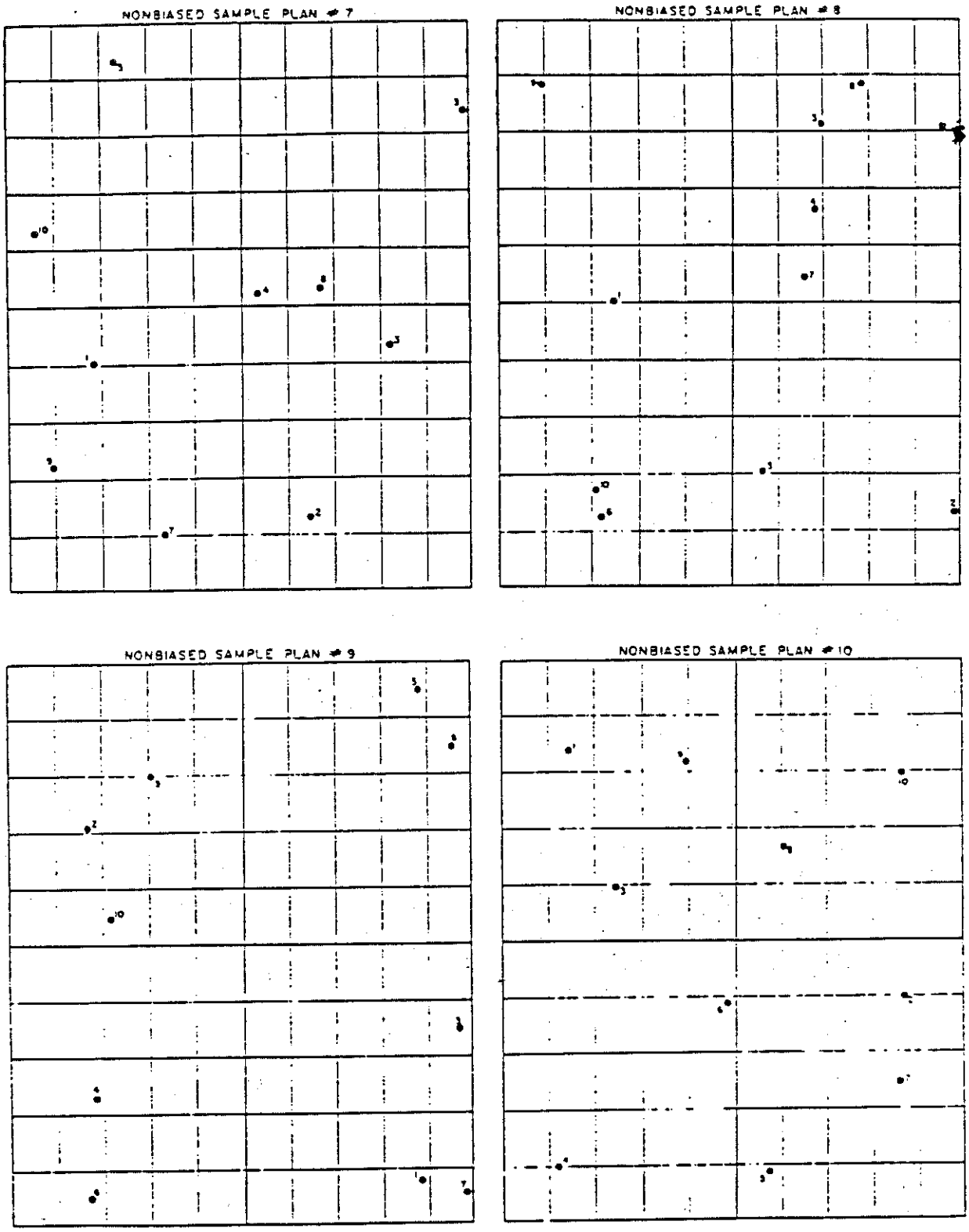


FIGURE 3 (Continued)

Appendix D
SAMPLE FORMS

Attached forms will be utilized for all field and laboratory reports.

1. Compaction Test
2. Grain Size Distribution
3. Atterberg Limits
4. Moisture Content and Dry Density Determination
5. Memorandum
6. Daily Field Report
7. Telephone/Verbal Conversation Record
8. Field Notes
9. Field Moisture-Density Test Sheet
10. Summary of Field Density Tests
11. Test Request Sheet

COMPACTION TEST

PROJECT NAME _____ PROJECT NO. _____ DATE _____

SAMPLE NO. _____ LOCATION _____ TESTED BY _____

SAMPLE DESCRIPTION _____

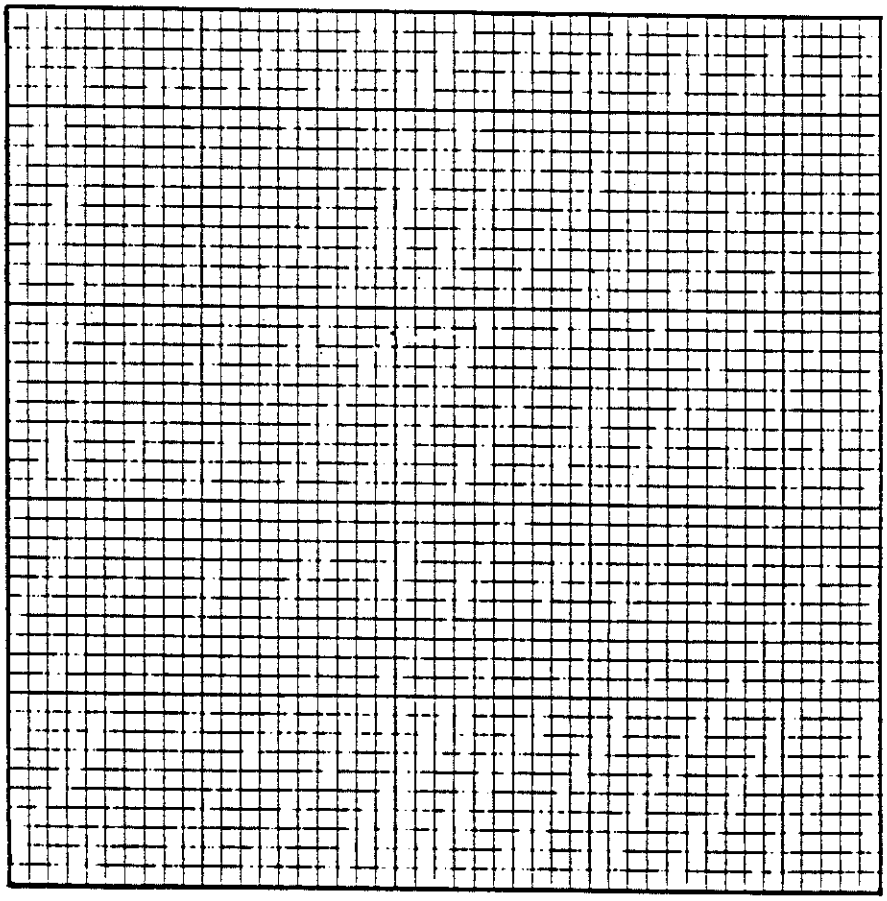
TRIAL NO.	1	2	3	4	5	6
ESTIMATED MOISTURE						
CONTAINER NO.						
CONTAINER + WET WT. (gms)						
CONTAINER + DRY WT. (gms)						
CONTAINER WT. (gms)						
WT. OF WATER (gms)						
DRY WT. OF SOIL (gms)						
MOISTURE CONTENT (%)						
WET WT. OF SOIL + MOLD (lb.)						
WT. OF MOLD (lb.)						
WET WT. OF SOIL (lb.)						
WET UNIT WT. (pcf)						
DRY UNIT WT. (pcf)						

MAXIMUM DRY UNIT WT.

_____ (pcf)

OPTIMUM WATER CONTENT

_____ (%)



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GRAIN SIZE DISTRIBUTION

PROJECT NAME _____ PROJECT NO. _____ DATE _____

SAMPLE NO. _____ DEPTH _____ TESTED BY _____

SAMPLE DESCRIPTION _____

MOISTURE CONTENT DETERMINATION

CUP NUMBER _____

CUP + WET SOIL _____ (gms)

CUP + DRY SOIL _____ (gms)

WEIGHT OF CUP _____ (gms)

WEIGHT OF MOISTURE _____ (gms)

WEIGHT OF DRY SOIL _____ (gms)

MOISTURE CONTENT _____ (%)

WET WEIGHT TOTAL SAMPLE _____ (gms)

DRY WEIGHT TOTAL SAMPLE

$$= \frac{\text{WET WEIGHT TOTAL SAMPLE}}{1 + (\text{MOISTURE CONTENT})} = \_\_\_\_\_ \text{(gms)}$$

SIEVE SIZE (U.S. STANDARD)	PARTICLE DIAMETER		WEIGHT RETAINED (gms)	ACCUMULATED WGT. RETAINED (gms)	WEIGHT PASSING (gms)	PERCENT PASSING
	INCH	MILLIMETER				
5"						
3"	3.0	76.2				
1 1/2"	1.5	38.1				
3/4"	0.742	18.85				
3/8"	0.371	9.42				
#4	0.185	4.699				
#8	0.093	2.362				
#16	0.046	1.168				
#30	0.0232	0.589				
#50	0.0116	0.295				
#100	0.0058	0.147				
#200	0.0029	0.074				
#270	0.0021	0.053				
PAN						
WEIGHT WASHED THROUGH #200						
TOTAL						

WEIGHT WASHED THROUGH #200

NUMBER OF PAN _____

WEIGHT PAN + DRY SOIL _____ (gms)

WEIGHT OF PAN _____ (gms)

WEIGHT DRY SOIL _____ (gms)

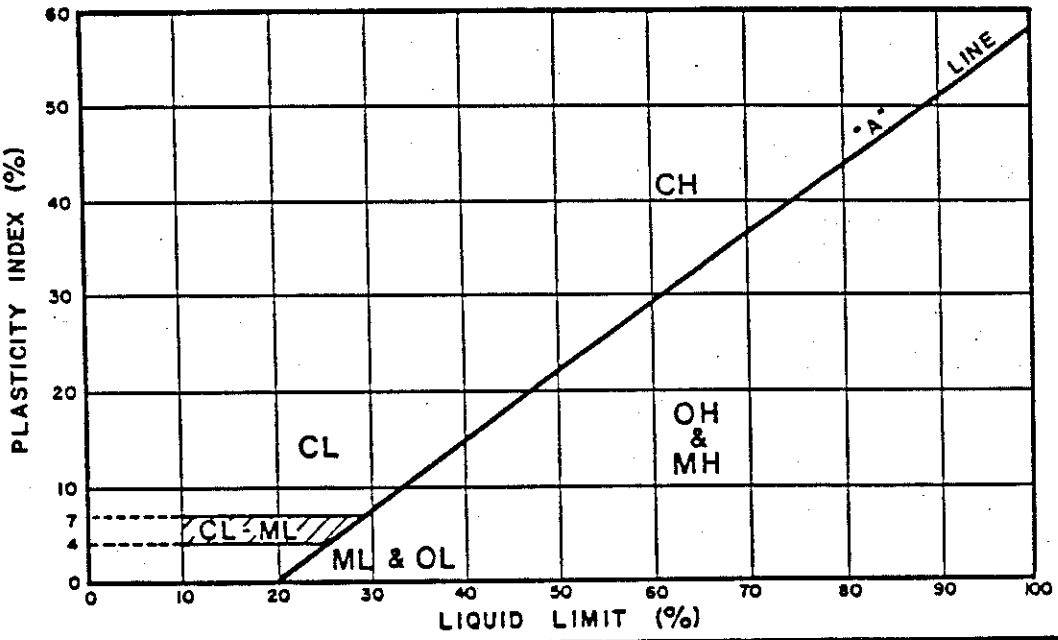
ATTERBERG LIMITS

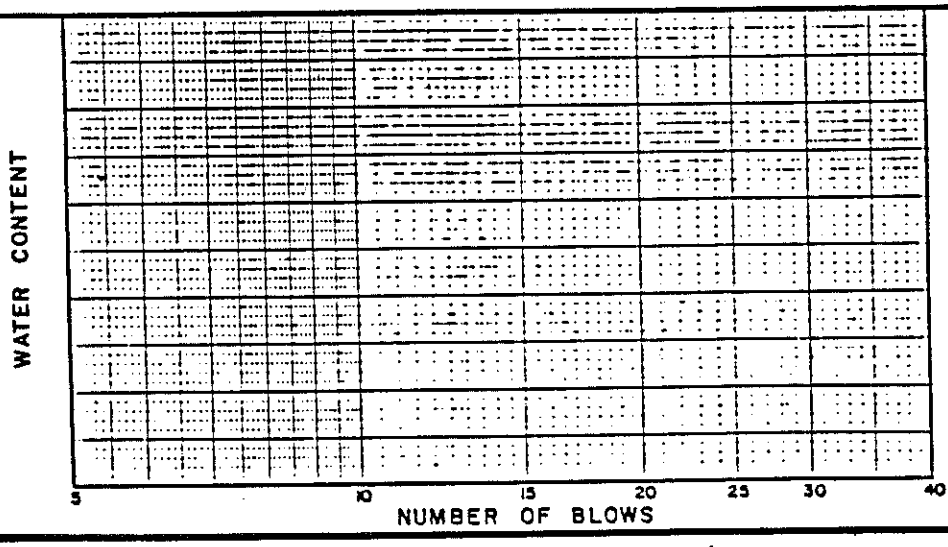
PROJECT NAME _____ PROJECT NO. _____ DATE _____

SAMPLE NO. _____ DEPTH _____ TESTED BY _____

SAMPLE DESCRIPTION _____

	LIQUID LIMIT				PLASTIC LIMIT		
CAN NO.							
WEIGHT OF CAN + WET SOIL (gms)							
WEIGHT OF CAN + DRY SOIL (gms)							
WEIGHT OF WATER (gms)							
WEIGHT OF CAN (gms)							
WEIGHT OF DRY SOIL (gms)							
WATER CONTENT (%)							
NUMBER OF BLOWS							





LIQUID LIMIT _____ %

PLASTIC LIMIT _____ %

PLASTICITY INDEX _____

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MOISTURE CONTENT - DRY DENSITY DETERMINATION

PROJECT NAME _____ PROJECT NUMBER _____

TESTED BY _____ DATE _____

SAMPLE NUMBER									
SAMPLE DEPTH (Ft.)									
USCS VISUAL CLASSIFICATION									
TARE NUMBER									
WET WEIGHT + TARE (gms)									
DRY WEIGHT + TARE (gms)									
WEIGHT OF MOISTURE (gms)									
WEIGHT OF TARE (gms)									
WEIGHT OF DRY SOIL (gms)									
MOISTURE CONTENT (%)									
SAMPLE DIAMETER (in.)									
SAMPLE LENGTH (in.)									
SAMPLE VOLUME (c.f.)									
WET DENSITY (pcf)									
DRY DENSITY (pcf)									

DAILY FIELD REPORT

CONSTRUCTION MANAGEMENT SERVICES

PROJECT NO. _____

PROJECT _____

LOCATION _____

DATE _____

WEATHER _____

CONTRACT DAYS REMAINING _____

CONTRACTOR'S EQUIPMENT _____

OBSERVATIONS _____

TIME ARRIVED _____ TIME DEPARTED _____

SIGNATURE _____

MEMORANDUM

Date _____

Project _____

To _____

Re _____

Headquarters:
1921 Ringwood Avenue, San Jose, California 95131, (408) 275-1444

Branch office: 445 W. Garfield Avenue, Glendale, California 91204

TELEPHONE / VERBAL CONVERSATION RECORD

DATE _____ PROJECT NO. _____

PROJECT NAME _____

FACILITY I.D. _____ PHONE (___) _____

CALL FROM _____ CALL TO _____

OR

PARTIES PRESENT AT CONFERENCE _____

SUMMARY OF CONVERSATION

PREPARED BY _____

COPY TO EACH PARTY: ☐ YES ☐ NO

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FIELD NOTES

DATE _____ PROJECT NO. _____

PROJECT NAME _____ FACILITY I.D. _____

BY _____

WEATHER: _____

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PROJECT NUMBER _____

PROJECT NAME _____

FACILITY I.D. _____

TESTED BY _____

GAUGE NO. _____

FIELD MOISTURE -DENSITY TEST SHEET

CURVE NO.	SOIL DESCRIPTION	MAX. DRY DENSITY PCF	OPTIMUM MOIST. %
1			
2			
3			
4			

TEST NO.	DATE	TEST COORDINATES	ELEV. (Ft.)	STD. COUNT DENS. / MOIST.	MODE AND DEPTH	DENSITY COUNT	DENSITY COUNT RATIO	WET DENSITY PCF	MOISTURE COUNT	MOISTURE COUNT RATIO	MOISTURE COUNT PCF	MOISTURE CONTENT %	DRY DENSITY PCF	REL. COMP. %	SOIL TYPE AND REMARKS
TEST NO.	DATE	TEST COORDINATES	ELEV. (Ft.)	INITIAL SAND	FINAL SAND	SAND USED	CONE SAND	TEST HOLE SAND	WET SOIL + PAN.	WET SOIL - PAN	MOISTURE DRY WT.	MOISTURE CONTENT %	DRY DENSITY PCF	REL. COMP. %	SOIL TYPE AND REMARKS

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SUMMARY OF FIELD DENSITY TESTS

PROJECT NO. _____ PROJECT NAME _____ PREPARED BY _____ DATE _____

FACILITY I.D. _____ CHECKED BY _____ DATE _____

TEST NO.	DATE	LOCATION	DEPTH BELOW FINAL GRADE (Ft.)	ELEV. (Ft.)	MOISTURE CONTENT (%)	DRY DENSITY (lbs/cu.ft.)	PERCENT COMPACTION	PERCENT COMPACTION SPECIFIED	REMARKS

COMPACTION TEST NO.				NOTES:
METHOD OF COMPACTION				
OPTIMUM MOISTURE CONTENT (%)				
MAXIMUM DRY DENSITY (lbs./cu. ft.)				

TEST REQUEST SHEET

PROJECT NAME _____ PROJECT NO. _____ LAB NO. _____

REQUESTED BY _____ PROJECT MANAGER APPOVAL _____ PAGE _____ OF _____

SAMPLE NUMBER	SAMPLE DEPTH LOCATION AND/OR STATION	VISUAL USCS SYMBOL	MOISTURE CONTENT	DRY DENSITY	ATTERBERG LIMITS	SIEVE ANALYSIS	# 200 WASH	HYDROMETER ANALYSIS	COMPACTION TEST	UNDISTURBED PERMEABILITY	DIRECT SHEAR	UNCONFINED COMPRESSION	REMOLDED PERMEABILITY			DATE REQUESTED	RESULTS DUE BY	DATE COMPLETED	DATE SAMPLE STORED	DATE SAMPLE DISPOSED OF

COMMENTS:

SAMPLES DELIVERED BY _____

SAMPLES RECEIVED BY _____

SPECIAL INSTRUCTIONS:

5/86

Appendix E

PERMEABILITY TEST PROTOCOL

Appendix E

PERMEABILITY TEST PROTOCOL

A flexible wall permeameter, which employs a triaxial type cell, should be used to determine the hydraulic conductivity of soil samples relative to water. (In this test procedure, hydraulic conductivity will be referred to as permeability.) Permeability is determined using the falling head method; a soil sample is placed in the cell, then continuous pressure is applied to the chamber and back pressure is applied to the sample through an air-water interface in calibrated burettes located on a control panel. The use of deaired water, combined with backpressure saturation, provides a high degree of saturation, which is critical in making an accurate determination of the permeability coefficient. Water is forced to permeate through the soil sample by creating a differential pressure across the sample from bottom to top. The hydraulic gradient can be controlled by regulating the pressure to simulate anticipated field conditions. When liquid inflow equals outflow, a series of burette readings are recorded and permeability is computed.

The following is a detailed procedure of the steps taken to arrive at the permeability coefficient.

EQUIPMENT DESCRIPTION

The basic components of a flexible wall permeameter include a control panel, burette panel, permeameter cell or chamber, and a pore pressure transducer. These components are described below:

1. Control Panel - The control panel contains three pressure regulators to independently control the pressures to the upper burette, lower burette, and the permeameter cell. Each regulator is provided with a gauge for accurate setting of all pressures.

2. Burette Panel - The burette panel contains the burettes for monitoring flow into and out of the sample. The lines from the burettes should be fitted with traps for isolating permeant in the event of over flow. The panel should have a reversing valve that will permit reversing the direction of flow, as well as valves that will allow for filling, draining, and adjusting the fluid levels in the burettes. The panel also contains a permeant reservoir and chamber reservoir.

3. Permeameter Cell or Chamber - The permeameter cell is a pressure chamber which accomodates the test sample. The cell has upper and lower influent-drainage lines and valves to allow flow through the sample, a cell pressure line, a cell vent line, and upper and lower flushing lines for saturating the porous stones.

4. Pore Pressure Transducer and Gauge - A pore pressure transducer and gauge should be connected to the lower flushing line to measure sample pore pressure in order to compute Skempton's "B" parameter and confirm sample saturation.

SAMPLE SET UP

1. Obtain a soil sample (undisturbed or remolded) and weigh it to the nearest 0.1 gm. Measure the specimen height and diameter to the nearest 0.01 cm.

2. Place a porous corundum stone, previously stored in water to maintain saturation, over the base pedestal of the triaxial cell.

3. Place a single layer of saturated filter paper over the porous stone.

4. Mount the soil sample on top of the filter paper.

5. Place a single layer of saturated filter paper on top of the soil sample.

6. Place a saturated, porous corundum stone on top of the filter paper and soil sample.

7. Mount the top cap on top of the porous stone.

8. Wrap a single strip of Teflon tape (0.50 in. wide) at the base pedestal and soil sample to completely cover the exposed edge of the porous stone. Use a similar strip of Teflon to wrap the top porous stone and seal the top cap and soil specimen.

9. Place one latex rubber membrane (0.025 in. wall thickness) over the base pedestal, soil sample, and top cap.

10. To secure the membrane(s) place two "O" rings around them at the bottom pedestal and top cap.

11. Attach the two drain lines to the top cap.

12. Check the base plate "O" ring seal to confirm that its groove has been properly sealed and that any obstructions have been removed.

13. Lower the lucite cylinder into place onto the "O" ring groove to enclose the chamber.

14. Check the top plate "O" ring seal to confirm that its groove has been properly sealed and that any obstructions have been removed.

15. Lower the top plate into place over the lucite cylinder, and tighten the wing nuts on the retainer bolts finger tight for a non-leaking seal.

16. Fill the chamber with deaired water.

PRESSURIZATION AND CONSOLIDATION

1. Saturate the three individual fluid lines (1/8 inch outside diameter) from the three burettes at the control unit by allowing drainage until no air bubbles are visible in any of the lines.

2. Attach the fluid lines to the cell at three locations: top, bottom, and chamber. Valves on the cell and control unit remain closed.

3. Open the fluid line valves at the control unit.

4. Open the fluid line valves on the cell.

5. Completely saturate both the top and bottom porous stones by opening the extra drain line valves and allowing drainage until no air bubbles are visible. Close these valves after saturation.

6. Using the regulators, increase the pressure (starting with the chamber line) in increments of 10 pounds per square inch gauge (psig) until the desired conditions are reached.

7. Pressurize the system to 100 psig confining pressure and predetermined bottom and top pressures.

8. Allow the soil sample to consolidate or swell during this stage of the test. Take burette readings to monitor consolidation or swell. Plot chamber burette reading versus time on semi-logarithm graph paper to determine when equilibrium is reached.

9. As the system reaches equilibrium, (burette readings will remain relatively constant), attach a pressure transducer and pressure indicator gauge to the extra valve on the bottom of the cell.

10. Close the top and bottom valves at the cell. Open the extra valve and increase the chamber pressure by 5 to 10 psig.

11. Record the increase in pressure in the indicator gauge and compute the Skempton "B" parameter. The "B" parameter is defined as the change in pore pressure divided by the change in confining pressure. If the "B" parameter is 0.95 or higher the sample is considered ready for permeation.

PERMEATION

1. Close the extra valve, disconnect the transducer and pressure gauge, and reopen the top and bottom valves on the cell. Reduce pressure at the top of the sample to 90 psig and increase the pressure at the bottom of the sample to 95 psig. This will create a hydraulic gradient across the sample, which begins the permeability test.

2. Monitor and record the fluid levels in the three burettes in the control unit.

3. When the volume of inflow equals outflow, compute the value of the permeability coefficient k by using the equation

$$K = \frac{aL}{2At} \ln \frac{H1}{H2}$$

Where: a = cross-sectional area of burette (cm^2)
L = sample height (cm)
A = cross-sectional area of sample (cm^2)
t = time between burette readings (sec)
H_1 = total hydrostatic head at first burette reading (cm)
H_2 = total hydrostatic head at second burette reading (cm)

Take several readings of t, H_1, and H_2 to verify a relatively constant value of the permeability coefficient.

SYSTEM SHUT DOWN

1. Depressurize the cell in 10 psig decrements (begin with the top and bottom fluid lines) until the pressure is 0 psig.

2. Close the cell and control unit valves and disconnect the fluid lines from the cell.

3. Take the cell to a sink and drain out the chamber water through the chamber valve.

4. Loosen the retainer bolt wing nuts and remove the lucite cylinder.

5. Remove the "O" rings around the membrane on the base pedestal and top cap.

6. Draw down the latex rubber membrane over the soil sample onto the base pedestal to fully expose the sample.

7. Remove the soil sample and weigh it to the nearest 0.1 gm. Measure the sample's height and diameter to the nearest 0.01 cm.

8. Oven dry the sample at 230°F for a minimum of 16 hours.

9. Compute before- and after-test values for the dry unit weight (γ_d), water content, void ratio (e), and degree of saturation (S). The specific gravity of the solid (G_s) is computed assuming S = 100 percent at the end of the test.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION V

DATE: Mar. 30'88

FROM: Gladys Beard, AIS

Docket Log No. 221

TO:
___ George Hamper-OH
___ Jim Mayka-IL
___ Hak K.Cho-IN
___ Richard Traub-MI
___ Chuck Slaustas-MN, WI

Reviewer: Jerry Lenssen GDL
UNIT #_____

Attached is the following:

PB Application ___ Subsequent ✓ Other ___ Received: 3-30'88 Dated: 3-29'88
Installation Name Chemical Waste Mgt.
Installation Address 3986 State Rt. 412 @ Vickery, OH
EPA ID# OHD 020 273 817

RECEIVED: 1 copy(s) 1 volume(s) ____ map(s) ____ blueprint(s)

____ attachment(s) ____ drawing(s)

Confidential Claimed NO If yes, see Gus Bloom for review of subject material.

Call-in Date_____ Voluntary Submittal Date _____

___ Existing Facility

___ New Facility
Action Required:

___ Notify Gladys (6-6162) of responsible person upon receipt of Part B.

___ Part A enclosed. - Please Review.
After Review Notify Gladys at(6-6162).

___ Voluntary Part B
Action Required:

° Notify Gladys (6-6162) if NEW or EXISTING facility.

° Notify Gladys (6-6162) of responsible person upon receipt of Part B.

° Provide Gladys Beard (6-6162) with Part B process codes.

☐ READY FOR PICKUP

Attachment 4

Quality Assurance Manual for the
Installation of the Soil Components
of Lining and Final Cover Systems,
dated June, 1986

Quality Assurance Manual For The Installation Of Geosynthetic Lining Systems

Waste Management of North America, Inc.
3003 Butterfield Road • Oak Brook, Illinois 60521

QUALITY ASSURANCE MANUAL FOR THE ASSURANCE OF GEOSYNTHETIC LINING SYSTEMS

June 15, 1990

QUALITY ASSURANCE MANUAL FOR THE INSTALLATION OF GEOSYNTHETIC LINING SYSTEMS

TABLE OF CONTENTS

APPENDICES

1.0 GENERAL

1.1 SCOPE

This Quality Assurance Manual (QAM) addresses the quality assurance of the installation of geosynthetic materials used by Chemical Waste Management, Inc. (WMNA) and Waste Management of North America, Inc., (WMNA) in their land disposal, surface impoundment, and other waste containment facilities. This manual is one component of the overall Quality Assurance Plan (QAP) developed for each project. Extreme care and detailed documentation are required in the production and installation of all geosynthetic materials used in waste containment applications.

This manual addresses quality assurance, not quality control. In the context of this manual, **quality assurance** refers to means and actions employed to assure conformity of the geosynthetic system production and installation with the project-specific Quality Assurance Plan (QAP), drawings, specifications, and contractual and regulatory requirements. Quality assurance is provided by a party independent from production and installation. **Quality control** refers only to those actions taken to ensure that materials and workmanship meet the requirements of the plans and specifications. Quality control is provided by the manufacturers and installers of the various components of the geosynthetic system.

A project-specific QAP is required for each project. At a minimum, the QAP shall consist of the following:

1. Applicable QAMs.

2. Project-Specific Addenda to the above QAMs. (Project-specific addenda shall be used to provide for additions, deletions, and changes necessary to the QAM(s) used for a particular project.)

3. Project-Specific Plans and Specifications.

The scope of this QAM applies to manufacturing, shipment, handling, and installation of geosynthetics. This QAM does not address design guidelines, installation specifications, or selection of geosynthetic materials. It also does not address the quality assurance of soils, except in cases where soil placement may have an influence on the geosynthetics. The quality assurance of soil components of landfill lining systems is addressed in the WMNA "Quality Assurance Manual for the Installation of Soil Components of Lining Systems".

This QAM was developed consistent with EPA guidance including "Construction Quality Assurance for Hazardous Waste Landfill Disposal Facilities," EPA/530-SW-86-031, October 1986, and regulations governing CQA requirements listed in 40 CFR 264.

1.2 PARTIES

The parties discussed in this section are associated with the ownership, design, manufacture, transportation, installation, and quality assurance of the geosynthetic system. The definitions, qualifications, and responsibilities of these parties are outlined in the following subsections.

1.2.1 Project Manager

1.2.1.1 Definitions

The Project Manager is the official representative of WMNA; in this manual, the term Project Manager shall apply equally to "Construction Coordinator", i.e., the individual responsible for coordinating construction and quality assurance activities for the project.

1.2.1.2 Responsibilities

The Project Manager is responsible for all construction quality assurance activities. The Project Manager is responsible for the organization and implementation of the QAP for the project as outlined in Section 1.1 of this manual.

The Project Manager shall serve as communications coordinator for the project, initiating the resolution, pre-construction, and construction meetings outlined in Section 1.3. As communications coordinator , the Project Manager shall serve as a liaison between all parties involved in the project to insure that communications are maintained.

The Project Manger shall also be responsible for proper resolution of all quality assurance issues that arise during construction.

1.2.1.3 Qualifications

The selection of the Project Manager is the direct responsibility of WMNA. Qualifications for this position include familiarity with the following:

1. Applicable QAMs.
2. General geosynthetic lining techniques.
3. All applicable regulatory requirements.
4. Company policies and procedures for project management.

1.2.2 Designer

1.2.2.1 Definitions

The Designer is the individual and/or firm responsible for the preparation of the design, including plans and project-specific specifications for the geosynthetic lining system.

1.2.2.2 Responsibilities

The Designer is responsible for performing the engineering design and preparing the associated drawings and specifications for the geosynthetic lining system. The Designer is responsible for approving all design and specification changes and making design clarifications necessitated during construction of the geosynthetic lining system. The Designer may attend the resolution and pre-construction meetings outlined in Section 1.3 of this manual upon the request of the Project Manager.

1.2.2.3 Qualifications

The Designer shall be a qualified engineer, certified or licensed as required by regulation. The Designer shall be familiar with geosynthetics (including detailed geosynthetic design methods and procedures) and applicable regulatory requirements.

1.2.2.4 Submittals

The Designer shall submit the project design drawings and specifications to the Project Manager. The Designer shall submit completed design clarification forms to the Project Manager in a timely manner upon request.

1.2.3 Manufacturer

1.2.3.1 Definitions

The Manufacturer is the firm responsible for production of any of the various geosynthetic liner system components outlined in this QAM.

1.2.3.2 Responsibilities

Each Manufacturer is responsible for the production of its geosynthetic product. In addition, each Manufacturer is responsible for the condition of the geosynthetic until the material is accepted by the Project Manager upon delivery. Each Manufacturer shall produce a consistent product meeting the project specifications. Each Manufacturer shall provide quality control documentation for its product as specified in this QAM.

1.2.3.3 Qualifications

Each Manufacturer shall be pre-qualified by WMNA. Each Manufacturer shall provide sufficient production capacity and qualified personnel to meet the demands of the project. Each Manufacturer shall have an internal quality control program for its product that meets the requirements presented in this QAM.

1.2.3.4 Submittals

Pre-qualification: A Manufacturer shall meet the following requirements and submit the following information to be considered for pre-qualification:

1. Corporate background and information

2. Manufacturing capabilities:

   a. Information on plant size, equipment, personnel, number of shifts per day, and capacity per shift.
   b. Daily production quantity available for WMNA facilities.
   c. A list of material properties including certified test results, to which are attached geosynthetic samples.
   d. A list of at least 15 completed landfill or surface impoundment facilities totalling a minimum of 15,000,000 ft^2 (1,500,000 m^2), for which the Manufacturer has manufactured a geosynthetic. For each facility, the following information shall be provided:

      (1) Name and purpose of facility, its location and date of installation.
      (2) Name of owner, project manager, designer, fabricator (if any) and installer.
      (3) Type of geosynthetic, surface area of geosynthetic manufactured.
      (4) Available information on the performance of the lining system and the facility.

3. The Manufacturer's quality control manual, including a description of the quality control laboratory facilities.

4. The origin (supplier's name and production plant) and identification (brand name and number) of resin used to manufacture the product.

5. A fingerprint of the Manufacturer's geosynthetic product (for polyethylene-based geosynthetics) in accordance with fingerprinting protocol listed in Appendix B of this QAM.

Pre-installation: Prior to the installation of any geosynthetic material, a Manufacturer must submit to the Project Manager all quality control documentation required by the appropriate section of this QAM. This documentation shall be reviewed by the

Geosynthetic Quality Assurance Consultant as outlined in Section 1.2.5 of this QAM before installation can begin.

1.2.4 Installer

1.2.4.1 Definitions

The Installer is the firm responsible for installation of the geosynthetics. The Installer may be affiliated with the Manufacturer.

The Superintendent is responsible for the Installer's field crew. The Superintendent shall represent the Installer at all site meetings and shall be responsible for acting as the Installer's spokesman on the project.

The Master Seamer shall be the most experienced seamer of the Installer's field crew. The Master Seamer shall provide direct supervision over less experienced seamers.

1.2.4.2 Responsibilities

The Installer shall be responsible for field handling, storing, deploying, seaming, temporary restraining and all other aspects of the geosynthetics installation. The Installer may also be responsible for transportation of these materials to the site and for anchor systems, if required by the project specifications. The Installer shall be responsible for submittal of the documentation listed in Section 1.2.4.4.

1.2.4.3 Qualifications

The Installer shall be pre-qualified and approved by WMNA. The Installer shall be able to provide qualified personnel to meet the demands of the project. At a minimum, the Installer shall provide a Superintendent and a Master Seamer as described below.

The Superintendent must be qualified based on previously demonstrated experience, management ability, and authority. The Superintendent, unless otherwise approved by the Project Manager, shall have previously managed, at a minimum, two installation projects which entailed the installation of at least a total of 1,000,000 ft^2 (100,000 m^2) of polyethylene geomembrane.

For geomembrane installation all personnel performing seaming operations shall be qualified by experience or by successfully passing seaming tests. The Master Seamer shall have experience seaming a minimum of 1,000,000 ft^2 (100,000 m^2) of polyethylene geomembrane using the same type of seaming apparatus to be used at the site.

1.2.4.4 Submittals

Pre-qualification: To be considered for pre-qualification, the Installer shall submit the following information:

1. Corporate background and information

2. Description of installation capabilities:
   a. Information on equipment (numbers and types), and personnel (number of superintendents, number of crews).
   b. Average daily production anticipated.
   c. Samples of field geomembrane seams and a list of minimum values for geomembrane seam properties.

3. A list of at least ten completed facilities, totalling a minimum of 2,000,000 ft^2 (200,000 m^2) for which the Installer has installed geosynthetics. For each installation, the following information shall be provided:
   a. Name and purpose of facility, its location, and date of installation.
   b. Name of owner, project manager, designer, manufacturer, fabricator (if any), and name of contact at the facility who can discuss the project .
   c. Name and qualifications of the Superintendent(s) of the Installer's crew(s).
   d. Type of geosynthetic, and surface area installed.
   e. Type of seaming and type of seaming apparatus used.
   f. Duration of installation.
   g. Available information on the performance of the lining system and the facility.

4. The Installer's quality control manual.

5. A copy of a letter of recommendation supplied by the geomembrane manufacturer.

Pre-installation: Prior to commencement of the installation, the Installer must submit to the Project Manager:

1. Resume of the Superintendent to be assigned to this project, including dates and duration of employment.
2. Resume of the Master Seamer to be assigned to this project, including dates and duration of employment.
3. A panel layout drawing showing the installation layout identifying field seams as well as any variance or additional details which deviate from the engineering drawings. The layout shall be adequate for use as a construction plan and shall include dimensions, details, etc.
4. Installation schedule.
5. A list of personnel performing field seaming operations along with pertinent experience information.

6. All geosynthetic quality control certificates as required by this QAM (unless submitted directly to the Project Manager by the Manufacturer).
7. Certification that extrudate to be used is comprised of the same resin as the geomembrane to be used.

This documentation shall be reviewed by the Geosynthetic Quality Assurance Consultant, as outlined in Section 1.2.5 of this QAM, before installation of the geosynthetic can begin.

Installation: During the installation, the Installer shall be responsible for the submission of:

1. Quality control documentation recorded during installation.
2. Subgrade surface acceptance certificates for each area to be covered by the lining system, signed by the Installer.

Completion: Upon completion of the installation, the Installer shall submit:

1. The warranty obtained from the Manufacturer.
2. The installation warranty.

1.2.5 Geosynthetic Quality Assurance Consultant

1.2.5.1 Definitions

The Geosynthetic Quality Assurance Consultant (QAC) is a firm independent from the Project Manager, Manufacturer(s), and Installer that shall be responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system on behalf of WMNA.

In this QAM the term Geosynthetic Quality Assurance Engineer (QAE) shall be used to designate the engineer (working for the Geosynthetic QAC) in charge of the quality assurance work. In some cases the duties of the Geosynthetic QAE described below may be shared by two individuals: a Geosynthetic Quality Assurance Managing Engineer located at the headquarters of the Geosynthetic QAC, and a Geosynthetic Quality Assurance Resident Engineer located at the site. The personnel of the Geosynthetic QAC also include Geosynthetic Quality Assurance Monitors who are located at the site for construction observation and documentation.

1.2.5.2 Responsibilities

The Geosynthetic QAC is responsible for observing and documenting activities related to the quality assurance of the production and installation of the geosynthetic system. The Geosynthetic QAC is responsible for implementation of the project QAP prepared by the Project Manager and management of the Geosynthetic Quality Assurance Laboratory. The

Geosynthetic QAC is also responsible for issuing a final certification report, sealed by a registered professional engineer, as outlined in Section 2.0 of this QAM.

The specific duties of the Geosynthetic QAC personnel are as follows:

1. The Geosynthetic QAE:

   a. Reviews all design drawings and specifications.
   b. Reviews other site-specific documentation, including proposed layouts, and manufacturer's and installer's literature.
   c. Develops a site-specific addendum for quality assurance of geosynthetics (if necessary) with the assistance of the Project Manager.
   d. Administers the geosynthetic portions of the QAP, e.g., assigns and manages all geosynthetic quality assurance personnel, reviews all field reports, and provides engineering review of all quality assurance related issues.
   e. Reviews all changes to design drawings and specifications as issued by the Designer.
   f. Acts as the on-site (resident) representative of the Geosynthetic QAC.
   g. Familiarizes all Geosynthetic Quality Assurance Monitors with the site and the project QAP.
   h. Attends all quality assurance related meetings, e.g., resolution, pre-construction, daily, weekly.
   i. Reviews all Manufacturer and Installer certifications and documentation and makes appropriate recommendations.
   j. Reviews the Installer's personnel qualifications for conformance with those qualifications pre-approved for work on site.
   k. Manages the preparation of the as-built drawing(s)
   l. Reviews the calibration certification of the on-site tensiometer, if applicable
   m. Reviews all Geosynthetic Quality Assurance Monitor's daily reports, logs and photographs.
   n. Notes any on site activities that could result in damage to the geosynthetics.
   o. Reports to the Project Manager, and logs in the daily report, any relevant observations reported by the Geosynthetic Quality Assurance Monitors.
   p. Prepares his own daily report.
   q. Prepares a daily summary of the quantities of geosynthetics installed that day.
   r. Prepares the weekly summary of geosynthetic quality assurance activities.
   s. Oversees the marking, packaging and shipping of all laboratory test samples.
   t. Reviews the results of laboratory testing and makes appropriate recommendations.
   u. Designates a Geosynthetic Quality Assurance Monitor to represent the QAE whenever he is absent from the site while operations are ongoing.
   v. Reports any unapproved deviations from the QAP to the Project Manager.
   w. Prepares the final certification report.

2. The Geosynthetic Quality Assurance Monitor:

   a. Monitors, logs, photographs and/or documents all geosynthetic installation operations. Photographs shall be taken routinely and in critical areas of the installation sequence. These duties shall be assigned by the Geosynthetic QAE.

   b. Monitors the following operations for all geosynthetics:

      (1) Material delivery
      (2) Unloading and on-site transport and storage
      (3) Sampling for conformance testing
      (4) Deployment operations
      (5) Joining and/or seaming operations
      (6) Condition of panels as placed
      (7) Visual inspection by walkover
      (8) Repair operations

   c. Monitors and documents the geomembrane seaming operations, including:

      (1) Trial seams
      (2) Seam preparation
      (3) Seaming
      (4) Nondestructive seam testing
      (5) Sampling for destructive seam testing
      (6) Field tensiometer testing
      (7) Laboratory sample marking
      (8) Repair operations

   d. Documents any on-site activities that could result in damage to the geosynthetics. Any problems noted shall be reported as soon as possible to the Geosynthetic QAE.

1.2.5.3 Qualifications

The Geosynthetic QAC shall be pre-qualified by WMNA. The Geosynthetic QAC shall be experienced in quality assurance of geosynthetics with emphasis on polyethylene geomembranes. The Geosynthetic QAC shall be experienced in the preparation of quality assurance documentation including: quality assurance forms, reports, certifications, and manuals.

The Geosynthetic Quality Assurance Managing Engineer shall hold a B.S., M.S. or Ph.D. engineering degree and be registered as a Professional Engineer. He shall also comply with the experience requirements listed in the previous paragraph. The Geosynthetic Quality Assurance Resident Engineer shall be specifically experienced in the installation of geosynthetics and shall be trained and certified by the Geosynthetic QAC in the duties of a Geosynthetic QAE.

Geosynthetic Quality Assurance Monitors shall be quality assurance personnel who have been specifically trained in the quality assurance of geosynthetics. At a minimum, one of every four monitors (or at least one monitor per project) shall have a minimum of 1,000,000 ft^2 (100,000 m^2) field experience in polyethylene geomembrane quality assurance.

1.2.5.4 Submittals

Pre-qualification: To be considered for pre-qualification, the Geosynthetic QAC must provide the following information:

1. Corporate background and information.

2. Quality assurance capabilities:
   a. A summary of the firm's experience with geosynthetics.
   b. A summary of the firm's experience in quality assurance, including installation quality assurance of geosynthetics.
   c. A summary of quality assurance documentation and methods used by the firm, including sample quality assurance forms, reports, certifications, and manuals prepared by the firm.
   d. Resumes of key personnel.

Pre-installation: Prior to beginning work on a project, the Geosynthetic QAC must provide the Project Manager with the following information:

1. Resumes of personnel to be involved in the project including Geosynthetic QAE, and Geosynthetic Quality Assurance Monitors.
2. Proof of professional engineering registration for the engineer to be designated as the Geosynthetic QAE, as well as proof of B.S., M.S., or Ph.D. engineering degree.
3. Proof of the required quality assurance experience of all of the quality assurance personnel with emphasis on polyethylene geomembranes.

1.2.6 Geosynthetic Quality Assurance Laboratory

1.2.6.1 Definitions

The Geosynthetic Quality Assurance Laboratory (QAL) is a firm, independent from the Project Manager, Manufacturer(s), and Installer, responsible for conducting tests on samples of geosynthetics taken from the site.

1.2.6.2 Responsibilities

The Geosynthetic QAL shall be responsible for conducting the appropriate laboratory tests as directed by the Geosynthetic QAE. The test procedures shall be done in accordance

with the test methods outlined in this QAM and/or the project QAP. The Geosynthetic QAL shall be responsible for providing test results as outlined in Section 1.2.6.4.

1.2.6.3 Qualifications

The Geosynthetic QAL shall have experience in testing geosynthetics and be familiar with American Society for Testing and Materials (ASTM), Federal Test Method Standard (FTMS), National Sanitation Foundation (NSF), and other applicable test standards. The Geosynthetic QAL shall be capable of providing verbal results of destructive seam tests within 24 hours of receipt of test samples and shall maintain that standard throughout the installation. The Geosynthetic QAL shall be approved by WMNA.

On-site laboratory facilities may be used by the Geosynthetic QAL, provided they are appropriately equipped and approved by the Geosynthetic QAC and the Project Manager.

1.2.6.4 Submittals

The Geosynthetic QAL shall submit all destructive seam test results to the Geosynthetic QAE in written form within 48 hours of receipt of test samples unless otherwise specified by the Project Manager. Geomembrane destructive test results shall typically be provided verbally to the Geosynthetic QAE within 24 hours of receipt of test samples. Written test results shall be in an easily readable format and include references to the standard test methods used.

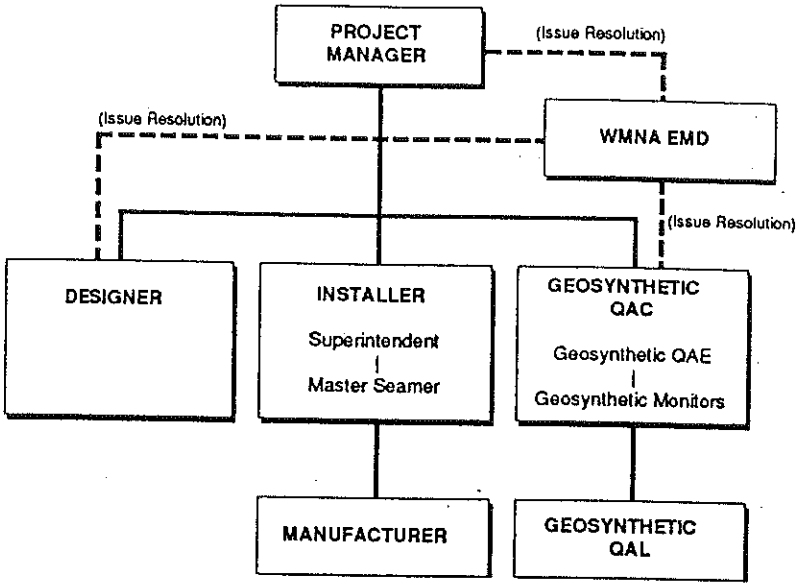
1.3 COMMUNICATION

To guarantee a high degree of quality during installation and assure a final product that meets all project specifications, clear, open channels of communication are essential. This section discusses appropriate lines of communication and describes all necessary meetings.

1.3.1 Lines of Communication

The typical lines of communication necessary during a project are illustrated in Exhibit 1-1. The Geosynthetic QAE shall be capable of direct communication with the Project Manager at all times. Access to WMNA Environmental Management Department (EMD) personnel is also available for issue resolution if necessary.

Exhibit 1-1
LINES OF COMMUNICATION



1.3.2 Resolution Meeting

Following permit approval and the completion of the construction drawings and specifications for the project, a resolution meeting may be held. If a resolution meeting is required, it is recommended that the meeting be held prior to bidding the construction work and include all parties then involved, typically including the Project Manager, Designer, Geosynthetic QAE, and a WMNA EMD representative. If necessary, this meeting can be held in conjunction with the pre-construction meeting.

The purpose of this meeting is to establish lines of communication, review construction drawings and specifications for completeness and clarity, begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and complete the QAP. All aspects of the design shall be reviewed during this meeting so that clarification and/or design changes may be made before the construction work is bid. In addition, the guidelines regarding quality assurance testing and problem resolution must be known and accepted by all.

A recommended agenda for the resolution meeting is presented in Exhibit 1-2. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.3 Pre-Construction Meeting

A pre-construction meeting shall be held at the site prior to beginning geosynthetic deployment. Typically, the meeting shall be attended by the Project Manager, Designer, Installer, Geosynthetic QAE, and a WMNA EMD representative.

Specific topics considered for this meeting include review of the project QAP for any problems or additions. In addition, the responsibilities of each party should be reviewed and understood clearly. A recommended agenda with specific topics for the pre-construction meeting is presented in Exhibit 1-3. The meeting shall be documented by a person designated at the beginning of the meeting, and minutes shall be transmitted to all parties.

1.3.4 Progress Meetings

A weekly progress meeting shall be held between the Geosynthetic QAE, Installer's Superintendent, Project Manager, and any other concerned parties. This meeting shall discuss current progress, planned activities for the next week, issues requiring resolution, and any new business or revisions to the work. The Geosynthetic QAE shall log any problems, decisions, or questions arising at this meeting in his weekly report. If any matter remains unresolved at the end of this meeting, the Project Manager shall be responsible for the resolution of the matter and the communication of the decision to the appropriate parties.

Exhibit 1-2
RESOLUTION MEETING AGENDA

1. Introductions

   A. Assign Minute Taker

   B. Identify Parties

      1. Project Manager
      2. Designer
      3. Geosynthetic Quality Assurance Consultant
      4. WMNA EMD representative
      5. Others

2. Distribution of Documents

   A. Design and Construction Drawings
   B. Specifications
   C. Construction Quality Assurance (CQA) Manuals
   D. Permit Documents

3. Review Construction Drawings and Specifications

   A. Tour Project Site

4. Complete Quality Assurance Plan (QAP)

   A. Project-specific Addendum to Quality Assurance Manual(s) (QAM(s))
   B. Project-specific Addendum to specifications

5. Contract Administration and Construction Issues

6. Define Lines of Communication

7. Project Deliverables

8. Schedule

Exhibit 1-3
PRE-CONSTRUCTION MEETING AGENDA

1. Introductions

   A. Assign Minute Taker

   B. Identify Parties

      1. Project Manager
      2. Installer
      3. Geosynthetic Quality Assurance Consultant
      4. Surveyor
      5. Designer
      6. Geosynthetic Quality Assurance Laboratory
      7. WMNA EMD Representative

2. Distribution of Documents

   A. Design and Construction Drawings and Specifications
   B. Geosynthetic Panel Layout
   C. Project QAP

3. Lines of Communication

   A. Lines of Communication
   B. Reporting Methods
   C. Progress Meetings
   D. Procedures for Approving Design Clarifications and Changes During Construction

4. Tour Project Site

5. Site Requirements

   A. Safety Rules
   B. Site Rules
   C. Work Schedule
   D. Storage of Materials
   E. Available Facilities

Exhibit 1-3 Continued
PRE-CONSTRUCTION MEETING AGENDA

5. Construction Issues

   A. Scope of Work
   B. Review Design
      1. Design and Construction Drawings and Specifications
      2. Geosynthetic Panel Layout
   C. Construction Procedures
      1. Proposed Construction Sequencing
      2. Equipment
   D. Construction Schedule
   E. Procedures for Preparing and Approving Change Orders

6. Construction Quality Assurance Plan

   A. Soils
   B. Geosynthetics
   C. Structural Systems (e.g., risers, piping, etc.)

7. Project Deliverables

   A. Responsibilities
      1. Designer
      2. Installer
      3. Geosynthetic Quality Assurance Consultant
      4. Geosynthetic Quality Assurance Laboratory
      5. Project Manager
   B. Distribution of Deliverables
   C. Approval Procedures

2.0 DOCUMENTATION

An effective QAP depends largely on identification of all construction activities that shall be monitored, and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Geosynthetic QAC shall document that all requirements in the geosynthetic portions of the project QAP have been addressed and satisfied.

The Geosynthetic QAC shall provide the Project Manager with signed descriptive remarks, data sheets, and checklists to verify that all monitoring activities have been carried out. The Geosynthetic QAC shall also maintain at the job site a complete file of all documents which comprise the QAP, including plans and specifications, this QAM, checklists, test procedures, daily logs, and other pertinent documents.

2.1 DAILY REPORTS

Each Geosynthetic Quality Assurance Monitor shall complete a daily report and/or logs on prescribed forms, outlining all monitoring activities for that day. The precise areas, panel numbers, seams completed and approved, and measures taken to protect unfinished areas overnight shall be identified. Failed seams or other panel areas requiring remedial action shall be identified with regard to nature of action, required repair, and precise location. Repairs completed must also be identified. Any problems or concerns with regard to operations on site should also be noted. This report must be completed at the end of each monitor's shift, prior to leaving the site, and submitted to the Geosynthetic QAC.

The Geosynthetic QAE shall review the daily reports submitted by the Geosynthetic Quality Assurance Monitors, and incorporate a summary of their reports into the Geosynthetic QAE's daily report. Any matters requiring action by the Project Manager shall be identified. The report shall include a summary of the quantities of all geosynthetics installed that day. This report must be completed daily, summarizing the previous day's activities, and a copy submitted to the Project Manager at the beginning of the work day following the report date.

2.2 DESTRUCTIVE TESTING REPORTS

The destructive test reports from all sources shall be collated by the Geosynthetic QAC. This includes field tests, Installer's laboratory tests (if performed), and Geosynthetic QAL tests. A summary list of test samples pass/fail results shall be prepared by the Geosynthetic QAC on an ongoing basis, and submitted with the weekly progress reports.

2.3 PROGRESS REPORTS

Progress reports shall be prepared by the Geosynthetic QAE and submitted to the Project Manager. These reports shall be submitted every week, starting the first Friday of geosynthetics deployment on site. This report shall include: an overview of progress to

date; an outline of any changes made to the plans, drawings, or specifications; any problems or deficiencies in installation at the site, and an outline of any action taken to remedy the situation(s); a summary of weather conditions; and a brief description of activities anticipated for the next reporting period.

All Geosynthetic QAE daily reports for the period should be appended to each progress report.

2.4 AS-BUILT DRAWINGS

As-built drawings shall be prepared by the Geosynthetic QAC. The as-built drawings shall include, at a minimum, the following information for geomembranes:

1. Dimensions of all geomembrane field panels.
2. Location, as accurate as possible, of each panel relative to the site survey grid (furnished by the Project Manager).
3. Identification of all seams and panels with appropriate numbers or identification codes (see Section 4.5.1).
4. Location of all patches and repairs.
5. Location of all destructive testing samples.

The as-built drawings shall illustrate each layer of geomembrane, and, if necessary, another drawing shall identify problems or unusual conditions of the geotextile or geonet layers. In addition, applicable cross-sections shall show layouts of geonets, geotextiles or geogrids in sump areas or any other areas which are unusual or differ from the design drawings.

2.5 FINAL CERTIFICATION REPORT

A final certification report shall be submitted upon completion of the work. This report shall summarize the activities of the project, and document all aspects of the quality assurance program performed.

The final certification report shall include, at a minimum, the following information:

1. Parties and personnel involved with the project
2. Scope of work
3. Outline of project
4. Quality assurance methods
5. Test results (conformance, destructive and non-destructive, including laboratory tests)
6. Certification, sealed and signed by a registered professional engineer
7. As-built drawings, sealed and signed by a registered professional engineer

The Geosynthetic QAC shall certify in the report that the installation has proceeded in accordance with the project QAP except as noted to the Project Manager. A recommended outline for the final certification report is given in Exhibit 2-1.

Exhibit 2-1
FINAL CONSTRUCTION QUALITY ASSURANCE CERTIFICATION REPORT
GENERAL OUTLINE

1. Introduction
   - Purpose
   - Scope
   - Unit Description

2. Project Specifications
   - Scope
   - Design Changes

3. Quality Assurance Plan
   - Scope
   - Project-Specific Addenda

4. Quality Assurance Work Performed
   - Weather Constraints
   - Conformance Testing
   - Visual Monitoring
   - Nondestructive Testing
   - Destructive Testing
   - Repairs

5. Summary and Conclusions

6. Project Certification

7. Appendices
   - Geosynthetic and/or Soils QAC Personnel
   - Contractor Personnel
   - Quality Assurance Plan (QAP) and Specification Modifications
   - Design Change Forms
   - Earthwork Testing Records (if required)
   - Conformance Testing Records
   - Manufacturer Quality Control Records
   - Quality Assurance Reports
   - Subgrade Acceptance Certificates
   - Panel Placement Records
   - Non-Destructive Seam Testing Records
   - Destructive Seam Testing Records
   - Repairs
   - As-Built Drawings

3.0 LINING SYSTEM ACCEPTANCE

Upon written recommendation by the Geosynthetic QAC, the Project Manager shall consider accepting the geosynthetic lining system. The conditions of acceptance are described below. The Installer and Manufacturer(s) will retain all ownership and responsibility for the geosynthetics in the lining system until acceptance by WMNA. At WMNA's discretion, the geosynthetic lining system may be accepted in sections or at points of substantial completion (see Appendix C).

The geosynthetic lining system will be accepted by WMNA when:

1. The installation of the lining system, or section thereof, is finished.
2. Verification of the adequacy of all seams and repairs, including associated testing, is completed.
3. All documentation of installation is completed.
4. The Geosynthetic QAC is able to recommend acceptance.

The Geosynthetic QAC shall certify that installation has proceeded in accordance with the geosynthetic portions of the project QAP except as noted to the Project Manager. This certification shall be provided in the final certification report as outlined in Section 2.5.

4.0 GEOMEMBRANES

4.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct an annual inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative, may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geomembrane rolls for that particular project. The purpose of the plant inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of handling, storage, and transportation procedures, and verification that these procedures will not damage the geomembrane.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geomembrane, thickness, roll number, and roll dimensions.
6. Verification that extrusion rods and/or beads are produced from the same base resin type as the geomembrane.

A report describing the inspection shall be retained by WMNA for annual inspections and by the Project Manager for project-specific inspections.

4.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geomembrane material, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geomembrane meets the WMNA specifications (see Appendix A).
4. Reports on quality control tests conducted by the Manufacturer to verify that the geomembrane manufactured for the project meets the project specifications.
5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2% by weight.

6. A list of the materials which comprise the geomembrane, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
7. A specification for the geomembrane which includes all properties contained in the WMNA specifications (see Appendix A) measured using the appropriate test methods.
8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
9. A characterization of the geomembrane based on the results of fingerprinting tests listed in Appendix B of this QAM.
10. Quality control certificates, signed by a responsible party employed by the Manufacturer. Each quality control certificate shall include roll identification numbers, sampling procedures, and results of quality control tests. At a minimum, results shall be given for:

    a. Density
    b. Carbon black content
    c. Carbon black dispersion
    d. Thickness
    e. Tensile properties
    f. Tear resistance

    These quality control tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A), for every 40,000 ft^2 (4,000 m^2) of geomembrane produced.

The Manufacturer shall identify all rolls of geomembranes with the following:

1. Manufacturer's name
2. Product identification
3. Thickness
4. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Rolls are appropriately labeled.
5. Certified minimum properties meet the WMNA specifications (see Appendix A).

4.3 CONFORMANCE TESTING

Upon delivery of the rolls of geomembrane, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geomembrane. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the WMNA specifications (see Appendix A).

If the Project Manager desires, the Geosynthetic QAC can perform the conformance test sampling at the manufacturing plant. This may be advantageous in expediting the installation process for very large projects.

The following conformance tests shall be conducted:

1. Density
2. Carbon black content
3. Carbon black dispersion
4. Thickness
5. Tensile characteristics

These conformance tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A).

4.3.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geomembrane.

4.3.2 Test Results

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geomembrane.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAE shall be

responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

4.4 SUBGRADE PREPARATION

4.4.1 Surface Preparation

The earthwork contractor shall be responsible for preparing the supporting soil for geomembrane placement. The Project Manager shall coordinate the work of the earthwork contractor and the Installer so that the requirements of the specifications and the project QAP are met.

Before the geomembrane installation begins, the Geosynthetic QAC shall verify that:

1. A qualified land surveyor has verified all lines and grades.
2. A qualified geotechnical engineer has verified that the supporting soil meets the density specified in the project specifications.
3. The surface to be lined has been rolled, compacted, or handworked so as to be free of irregularities, protrusions, loose soil, and abrupt changes in grade.
4. The surface of the supporting soil does not contain stones which may be damaging to the geomembrane.
5. There is no area excessively softened by high water content.

6. There is no area where the surface of the soil contains desiccation cracks with dimensions exceeding those allowed by the project specifications.

The Installer shall certify in writing that the surface on which the geomembrane will be installed is acceptable. A certificate of acceptance (see Appendix C) shall be given by the Installer to the Geosynthetic QAC prior to commencement of geomembrane deployment in the area under consideration. The Project Manager shall be given a copy of this certificate by the Geosynthetic QAC.

After the supporting soil has been accepted by the Installer, it is the Installer's responsibility to indicate to the Project Manager any change in the supporting soil condition that may require repair work. The Project Manager may consult with the Geosynthetic QAC regarding the need for repairs. If the Geosynthetic QAC concurs with Installer, the Project Manager shall ensure that the supporting soil is repaired.

At any time before or during the geomembrane installation, the Geosynthetic QAC shall indicate to the Project Manager any locations which may not be adequately prepared for the geomembrane.

4.4.2 Anchor Trench

The Geosynthetic QAC shall verify that the anchor trench has been constructed according to the design drawings and specifications.

If the anchor trench is excavated in a clay material susceptible to desiccation, the amount of trench open at any time should be minimized. The Geosynthetic QAC shall inform the Project Manager of any signs of significant desiccation associated with the anchor trench construction.

Slightly rounded corners shall be provided in the trench so as to avoid sharp bends in the geomembrane. Excessive amounts of loose soil shall not be allowed to underlie the geomembrane in the anchor trench.

The anchor trench shall be adequately drained to prevent ponding or softening of the adjacent soils while the trench is open. The anchor trench shall be backfilled and compacted as outlined in the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geosynthetics. The Geosynthetic QAC shall observe the backfilling operation and advise the Project Manager of any problems. Any problems shall be documented by the Geosynthetic QAC in his daily report.

4.5 GEOMEMBRANE DEPLOYMENT

4.5.1 Panel Nomenclature

A field panel is defined as a unit of geomembrane which is to be seamed in the field, i.e., a field panel is a roll or a portion of roll cut in the field.

It shall be the responsibility of the Geosynthetic QAC to ensure that each field panel is given an identification code (number or letter-number) consistent with the layout plan. This identification code shall be agreed upon by the Project Manager, Installer and Geosynthetic QAC. This field panel identification code shall be as simple and logical as possible. In general, it is not appropriate to identify panels using roll numbers since roll numbers established in the manufacturing plant are usually cumbersome and are not related to location in the field. The Geosynthetic QAC shall establish a table or chart showing correspondence between roll numbers and field panel identification codes. The field panel identification code shall be used for all quality assurance records.

The Geosynthetic QAC shall verify that field panels are installed at the locations indicated on the Installer's layout plan, as approved by the Project Manager.

4.5.2 Panel Deployment Procedure

The Geosynthetic QAC shall review the panel deployment progress of the Installer (keeping in mind issues relating to wind, rain, clay liner desiccation, and other site-specific conditions) and advise the Project Manager on its compliance with the approved panel layout drawing and its suitability to the actual field conditions. Once approved, only the Project Manager can authorize changes to the panel deployment procedure. The Geosynthetic QAC shall verify that the condition of the supporting soil does not change detrimentally during installation.

The Geosynthetic QAC shall record the identification code, location, and date of installation of each field panel.

4.5.3 Deployment Weather Conditions

Geomembrane deployment shall not proceed at an ambient temperature below 32°F (0°C) or above 104°F (40°C) unless otherwise authorized, in writing, by the Project Manager. Geomembrane placement shall not be performed during any precipitation, in the presence of excessive moisture (e.g., fog, dew), in an area of ponded water, or in the presence of excessive winds. Geomembrane deployment shall not be undertaken if weather conditions will preclude material seaming following deployment.

The Geosynthetic QAC shall verify that the above conditions are fulfilled. Ambient temperature shall be measured by the Geosynthetic QAC in the area in which the panels

are to be deployed. The Geosynthetic QAC shall inform the Project Manager of any weather related problems which may not allow geomembrane placement to proceed.

4.5.4 Method of Deployment

Before the geomembrane is handled on site, the Geosynthetic QAC shall verify that handling equipment to be used on the site is adequate and does not pose risk of damage to the geomembrane. During handling, the Geosynthetic QAC shall observe and verify that the Installer's personnel handle the geomembrane with care.

The Geosynthetic QAC shall verify the following:

1. Any equipment used does not damage the geomembrane by handling, trafficking, excessive heat, leakage of hydrocarbons, or other means.
2. The prepared surface underlying the geomembrane has not deteriorated since previous acceptance, and is still acceptable immediately prior to geomembrane placement.
3. Any geosynthetic elements immediately underlying the geomembrane are clean and free of debris.
4. All personnel do not smoke or wear damaging shoes while working on the geomembrane, or engage in other activities which could damage the geomembrane.
5. The method used to unroll the panels does not cause excessive scratches or crimps in the geomembrane and does not damage the supporting soil.
6. The method used to place the panels minimized wrinkles (especially differential wrinkles between adjacent panels).
7. Adequate temporary loading and/or anchoring (e.g., sand bags, tires), not likely to damage the geomembrane, has been placed to prevent uplift by wind. In case of high winds, continuous loading, e.g., by sand bags, is recommended along edges of panels to the minimize risk of wind flow under the panels.
8. Direct contact with the geomembrane is minimized, and the geomembrane is protected by geotextiles, extra geomembrane, or other suitable materials, in areas where excessive traffic may be expected.

The Geosynthetic QAC shall inform the Project Manager if the above conditions are not fulfilled.

4.5.5 Damage and Defects

Upon delivery to the site, the Geosynthetic QAC shall conduct a surface observation of all rolls for defects and for damage. This inspection shall be conducted without unrolling rolls unless defects or damages are found or suspected. The Geosynthetic QAC shall advise the Project Manager, in writing, of any rolls or portions of rolls which should be rejected and removed from the site because they have severe flaws, and/or minor repairable flaws.

The Geosynthetic QAC shall inspect each panel, after placement and prior to seaming, for damage and/or defects. The Geosynthetic QAC shall advise the Project Manager which

panels, or portions of panels, should be rejected, repaired, or accepted. Damaged panels, or portions of damaged panels, which have been rejected shall be marked and their removal from the work area recorded by the Geosynthetic QAC. Repairs shall be made using procedures described in Section 4.9.

4.5.6 Writing on the Liner

To avoid confusion, the Installer and the Geosynthetic QAC shall each use different colored markers that are readily visible for writing on the geomembrane. The markers used must be semi-permanent and compatible with the geomembrane. The Installer shall use a white marker to write on the geomembrane. The Geosynthetic QAC shall use a yellow marker.

4.6 FIELD SEAMING

4.6.1 Seam Layout

Before installation begins, the Installer must provide the Project Manager and the Geosynthetic QAC with a panel layout drawing, i.e., a drawing of the facility to be lined showing all expected seams. The Geosynthetic QAE shall review the panel layout drawing and verify that it is consistent with accepted state-of-practice. No panels may be seamed without the written approval of the panel layout drawing by the Project Manager. In addition, panels not specifically shown on the panel layout drawing may not be used without the Project Manager's prior approval.

In general, seams should be oriented parallel to the line of maximum slope, i.e., oriented along, not across, the slope. In corners and odd-shaped geometric locations, the number of seams should be minimized. No horizontal seam should be less than 5 ft (1.5 m) from the toe of the slope, or areas of potential stress concentrations, unless otherwise authorized by the Project Manager.

A seam numbering system compatible with the panel numbering system shall be used by the Geosynthetic QAC.

4.6.2 Accepted Seaming Methods

Approved processes for field seaming are extrusion welding and fusion welding. Proposed alternate processes shall be documented and submitted by the Installer to the Project Manager for approval. Only apparatus which have been specifically approved by make and model shall be used. The Project Manager shall submit all documentation regarding seaming methods to be used to the Geosynthetic QAC for review.

4.6.2.1 Extrusion Process

The Geosynthetic QAC shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager.

The Geosynthetic QAC shall verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.
2. Equipment used for seaming is not likely to damage the geomembrane.
3. Prior to beginning a seam, the extruder is purged until all heat-degraded extrudate has been removed from the barrel.
4. Clean and dry welding rods or extrudate pellets are used.
5. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.
6. Grinding shall be completed no more than 1 hour prior to seaming.
7. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.
8. The geomembrane is protected from damage in heavily trafficked areas.
9. Exposed grinding marks adjacent to an extrusion weld shall be minimized. In no instance shall exposed grinding marks extend more than 1/4" from the seamed area.
10. In general, the geomembrane panels are aligned to have a nominal overlap of 3 in (75 mm) for extrusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.
11. No solvent or adhesive is used unless the product is approved in writing by the Project Manager prior to use (samples shall be submitted to the Project Manager for testing and evaluation).
12. The procedure used to temporarily bond adjacent panels together does not damage the geomembrane; in particular, the temperature of hot air at the nozzle of any temporary welding apparatus is controlled such that the geomembrane is not damaged or degraded.

4.6.2.2 Fusion Process

The Geosynthetic QAC shall log ambient, seaming apparatus, and geomembrane surface temperatures at appropriate intervals and report any noncompliances to the Project Manager.

The Geosynthetic QAC shall also verify that:

1. The Installer maintains on-site the number of spare operable seaming apparatus decided upon at the pre-construction meeting.
2. Equipment used for seaming is not likely to damage the geomembrane.
3. For cross seams, the edge of the cross seam is ground to an incline prior to welding.

4. The electric generator is placed on a smooth base such that no damage occurs to the geomembrane.
5. A smooth insulating plate or fabric is placed beneath the hot welding apparatus after usage.
6. The geomembrane is protected from damage in heavily trafficked areas.
7. A movable protective layer is used as required by the Installer directly below each overlap of geomembrane that is to be seamed to prevent buildup of moisture between the sheets and prevent debris from collecting around the pressure rollers.
8. In general, the geomembrane panels are aligned to have a nominal overlap of 5 in (125 mm) for fusion welding. In any event, the final overlap shall be sufficient to allow peel tests to be performed on the seam.
9. No solvent or adhesive is used unless the product is approved in writing by the Project Manager prior to use (samples shall be submitted to the Project Manager for testing and evaluation).

4.6.3 Seam Preparation

The Geosynthetic QAC shall verify that prior to seaming, the seam area is clean and free of moisture, dust, dirt, debris or foreign material of any kind. If seam overlap grinding is required, the Geosynthetic QAC must ensure that the process is completed according to the Manufacturer's instructions within one hour of the seaming operation, and in a way that does not damage the geomembrane. The Geosynthetic QAC shall also verify that seams are aligned with the fewest possible number of wrinkles and "fishmouths".

4.6.4 Trial Seams

Trial seams shall be made on fragment pieces of geomembrane liner to verify that conditions are adequate for production seaming. Such trial seams shall be made at the beginning of each seaming period, and at least once each five hours, for each production seaming apparatus used that day. Each seamer shall make at least one trial seam each day. Trial seams shall be made under the same conditions as actual seams.

The trial seam sample shall be at least 5 ft (1.0 m) long by 1 ft (0.3 m) wide (after seaming) with the seam centered lengthwise. Seam overlap shall be as indicated in Section 4.6.2.

Two specimens shall be cut from the sample with a 1 in (25 mm) wide die. The specimens shall be cut by the Installer at locations selected randomly along the trial seam sample by the Geosynthetic QAC. The specimens shall be tested in peel using a field tensiometer. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. They should not fail in the seam as described in Section 4.8.5. If a specimen fails, the entire operation shall be repeated. If the additional specimen fails, the seaming apparatus and seamer shall not be accepted and shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial welds are achieved. The Geosynthetic QAC shall observe all trial seam procedures.

The remainder of the successful trial seam sample shall be cut into three pieces, one to be retained in the Project Manager's archives, one to be given to the Installer, and one to be retained by the Geosynthetic QAC for possible laboratory testing. Each portion of the sample shall be assigned a number and marked accordingly by the Geosynthetic QAC, who shall also log the date, hour, ambient temperature, number of seaming unit, name of seamer, and pass or fail description.

If agreed upon between the Project Manager and the Geosynthetic QAE, and documented by the Geosynthetic QAE in his daily report, the remaining portion of the trial seam sample can be subjected to destructive testing as indicated in Section 4.8.6. If a trial seam sample fails a test conducted by the Geosynthetic QAL, then a destructive seam test sample shall be taken from each of the seams completed by the seamer during the shift related to the considered trial seam. These samples shall be forwarded to the Geosynthetic QAL and, if they fail the tests, the procedure indicated in Section 4.8.7 shall apply. The conditions of this paragraph shall be considered satisfied for a given seam if a destructive seam test sample has already been taken.

4.6.5 General Seaming Procedures

During general seaming, the Geosynthetic QAC shall be cognizant of the following:

1. For fusion welding, it may be necessary to place a movable protective layer of plastic directly below each overlap of geomembrane that is to be seamed. This is to prevent any moisture buildup between the sheets to be welded and prevent debris from collecting around the pressure rollers.
2. If required, a firm substrate shall be provided by using a flat board, a conveyor belt, or similar hard surface directly under the seam overlap to achieve proper support.
3. Fishmouths or wrinkles at the seam overlaps shall be cut along the ridge of the wrinkle in order to achieve a flat overlap. The cut fishmouths or wrinkles shall be seamed and any portion where the overlap is inadequate shall then be patched with an oval or round patch of the same geomembrane extending a minimum of 6 in (150 mm) beyond the cut in all directions.
4. If seaming operations are carried out at night, adequate illumination shall be provided.
5. Seaming shall extend to the outside edge of panels placed in the anchor trench.
6. All cross seam tees should be extrusion welded to a minimum distance of 4 in on each side of the tee.
7. No field seaming shall take place without the Master Seamer being present.

The Geosynthetic QAC shall verify that the above seaming procedures (or any other procedures agreed upon and indicated in the project QAP) are followed, and shall inform the Project Manager of any nonconformance.

4.6.6 Seaming Weather Conditions

4.6.6.1 Normal Weather Conditions

The normal required weather conditions for seaming are as follows:

1. Ambient temperature between 32°F (0°C) and 104°F (40°C).
2. Dry conditions, i.e. no precipitation or other excessive moisture, such as fog or dew.
3. No excessive winds.

The Geosynthetic QAE shall verify that these weather conditions are fulfilled and notify the Project Manager in writing if they are not. Ambient temperature shall be measured by the Geosynthetic QAC in the area in which the panels are to be placed. The Project Manager will then decide if the installation is to be stopped or special procedures used.

4.6.6.2 Cold Weather Conditions

To ensure a quality installation, if seaming is conducted when the ambient temperature is below 32°F (0°C), the following conditions must be met:

1. Geomembrane surface temperatures shall be determined by the Geosynthetic QAC at intervals of at least once per 100 foot of seam length to determine if preheating is required. For extrusion welding, preheating is required if the surface temperature of the geomembrane is below 32°F (0°C).
2. Preheating may be waived by the Project Manager based on a recommendation from the Geosynthetic QAE, if the Installer demonstrates to the Geosynthetic QAE's satisfaction that welds of equivalent quality may be obtained without preheating at the expected temperature of installation.
3. If preheating is required, the Geosynthetic QAC shall inspect all areas of geomembrane that have been preheated by a hot air device prior to seaming, to ensure that they have not been overheated.
4. Care shall be taken to confirm that the surface temperatures are not lowered below the minimum surface temperatures specified for welding due to winds or other adverse conditions. It may be necessary to provide wind protection for the seam area.
5. All preheating devices shall be approved prior to use by the Project Manager.
6. Additional destructive tests (as described in Section 4.8) shall be taken at an interval between 500 feet and 250 feet of seam length, at the discretion of the Geosynthetic QAE.
7. Sheet grinding may be performed before preheating, if applicable.
8. Trial seaming, as described in Section 4.6.4, shall be conducted under the same ambient temperature and preheating conditions as the actual seams. Under cold weather conditions, new trial seams shall be conducted if the ambient temperature drops by more than 5°F from the initial trial seam test conditions.

4.6.6.3 Warm Weather Conditions

At ambient temperatures above 104 °F, no seaming of the geomembrane shall be permitted unless the Installer can demonstrate to the satisfaction of the Project Manager that geomembrane seam quality is not compromised.

Trial seaming, as described in Section 4.6.4, shall be conducted under the same ambient temperature conditions as the actual seams.

At the option of the Geosynthetic QAC, additional destructive tests (as described in Section 4.8) may be required for any suspect areas.

4.7 NONDESTRUCTIVE SEAM TESTING

4.7.1 Concept

The Installer shall nondestructively test all field seams over their full length using a vacuum test unit, air pressure test (for double fusion seams only), or other approved method. Vacuum testing and air pressure testing are described in Sections 4.7.2 and 4.7.3 respectively. The purpose of nondestructive tests is to check the continuity of seams. It does not provide quantitative information on seam strength. Nondestructive testing shall be carried out as the seaming work progresses, not at the completion of all field seaming.

For all seams, the Geosynthetic QAC shall:

1. Observe nondestructive testing procedures.
2. Record location, data, test unit number, name of tester, and outcome of all testing.
3. Inform the Installer and Project Manager of any required repairs.

Any seams that cannot be nondestructively tested shall be cap-stripped with the same geomembrane. The cap-stripping operations shall be observed by the Geosynthetic QAC and Installer for uniformity and completeness.

4.7.2 Vacuum Testing

The following procedures are applicable to vacuum testing.

1. The equipment shall consist of the following:

    a. A vacuum box assembly consisting of a rigid housing, a transparent viewing window, a soft neoprene gasket attached to the bottom, a porthole or valve assembly, and a vacuum gauge.
    b. A pump assembly equipped with a pressure controller and pipe connections.
    c. A rubber pressure/vacuum hose with fittings and connections.

d. A soapy solution.
e. A bucket and wide paint brush, or other means of applying the soapy solution.

2. The following procedures shall be followed:

a. Energize the vacuum pump and reduce the tank pressure to approximately 5 psi (10 in of Hg) (35 kPa) gauge.
b. Wet a strip of geomembrane approximately 12 in x 48 in (0.3 m x 1.2 m) with the soapy solution.
c. Place the box over the wetted area.
d. Close the bleed valve and open the vacuum valve.
e. Ensure that a leak-tight seal is created.
f. For a period of not less than 10 seconds, apply vacuum and examine the geomembrane through the viewing window for the presence of soap bubbles.
g. If no bubble appears after 10 seconds, close the vacuum valve and open the bleed valve, move the box over the next adjoining area with a minimum 3 in (75 mm) overlap, and repeat the process.
h. All areas where soap bubbles appear shall be marked and repaired in accordance with Section 4.9.3.

4.7.3 Air Pressure Testing

The following procedures are applicable to double fusion welding which produces a double seam with an enclosed space.

1. The equipment shall consist of the following:
   a. An air pump (manual or motor driven), equipped with pressure gauge capable of generating and sustaining a pressure between 25 and 30 psi (160 and 200 kPa) and mounted on a cushion to protect the geomembrane.
   b. A rubber hose with fittings and connections.
   c. A sharp hollow needle, or other approved pressure feed device.

2. The following procedures shall be followed:

a. Seal both ends of the seam to be tested.
b. Insert needle or other approved pressure feed device into the air channel created by the fusion weld.
c. Insert a protective cushion between the air pump and the geomembrane.
d. Energize the air pump to a pressure between 25 and 30 psi (160 and 200 kPa), close valve, allow 2 minutes for pressure to stabilize, and sustain pressure for at least 5 minutes.
e. If loss of pressure exceeds 4 psi (30 kPa) or does not stabilize, locate faulty area and repair in accordance with Section 4.9.3.

f. Cut opposite end of tested seam area once testing is completed to verify continuity of the air channel. If air does not escape, locate blockage and retest unpressurized area. Seal the cut end of the air channel.
g. Remove needle or other approved pressure feed device and seal.

4.7.4 Test Failure Procedures

The Installer shall complete any required repairs in accordance with Section 4.9. For repairs, the Geosynthetic QAC shall:

1. Observe the repair and testing of the repair.
2. Mark on the geomembrane that the repair has been made.
3. Document the repair procedures and test results.

4.8 DESTRUCTIVE SEAM TESTING

4.8.1 Concept

Destructive seam tests shall be performed at selected locations. The purpose of these tests is to evaluate seam strength. Seam strength testing shall be done as the seaming work progresses, not at the completion of all field seaming.

4.8.2 Location and Frequency

The Geosynthetic QAC shall select locations where seam samples will be cut out for laboratory testing. Those locations shall be established as follows:

1. A minimum frequency of one test location per 500 ft (150 m) of seam length performed by each welder. This minimum frequency is to be determined as an average taken throughout the entire facility.
2. Test locations shall be determined during seaming at the Geosynthetic QAC's discretion. Selection of such locations may be prompted by suspicion of overheating, contamination, offset welds, or any other potential cause of imperfect welding.

The Installer shall not be informed in advance of the locations where the seam samples will be taken.

4.8.3 Sampling Procedures

Samples shall be cut by the Installer at locations chosen by the Geosynthetic QAC as the seaming progresses so that laboratory test results are available before the geomembrane is covered by another material. The Geosynthetic QAC shall:

1. Observe sample cutting.
2. Assign a number to each sample, and mark it accordingly.

3. Record sample location on layout drawing.
4. Record reason for taking the sample at this location (e.g., statistical routine, suspicious feature of the geomembrane).

All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in Section 4.9.3. The continuity of the new seams in the repaired area shall be tested according to Section 4.7.2.

4.8.4 Sample Dimensions

At a given sampling location, two types of samples shall be taken by the Installer. First, two samples for field testing should be taken. Each of these samples shall be cut with a 1 in (25 mm) wide die, with the seam centered parallel to the width. The distance between these two samples shall be 42 in (1.1 m). If both samples pass the field test described in Section 4.8.5, a sample for laboratory testing shall be taken.

The sample for laboratory testing shall be located between the samples for field testing. The sample for laboratory testing shall be 12 in (0.3 m) wide by 42 in (1.1 m) long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:

1. One portion to the Installer for optional laboratory testing, 12 in x 12 in. (0.3 m x 0.3 m)
2. One portion for Geosynthetic QAL testing, 12 in x 18 in (0.3 m x 0.5 m) and
3. One portion to the Project Manager for archive storage, 12 in x 12 in (0.3 m x 0.3 m).

Final determination of the sample sizes shall be made at the pre-construction meeting.

4.8.5 Field Testing

The two 1 in (25 mm) wide strips mentioned in Section 4.8.4 and Section 4.6.4 shall be tested in the field using a tensiometer for peel and shall not fail according to the criteria in Table A-2, Appendix A. The tensiometer shall be capable of maintaining a constant jaw separation rate of two inches per minute. If the test passes in accordance with this section, the sample qualifies for testing in the laboratory. If it fails, the seam should be repaired in accordance with Section 4.8.7. Final judgement regarding seam acceptability, based on the failure criteria, rests with the Geosynthetic QAE.

The Geosynthetic QAC shall witness all field tests and mark all samples and portions with their number. The Geosynthetic QAC shall also log the date and time, ambient temperature, number of seaming unit, name of seamer, welding apparatus temperatures and pressures, and pass or fail description, and attach a copy to each sample portion.

4.8.6 Laboratory Testing

Destructive test samples shall be packaged and shipped, if necessary, under the responsibility of the Geosynthetic QAC in a manner which will not damage the test sample. The Project Manager will be responsible for storing the archive samples. Test samples shall be tested by the Geosynthetic QAL.

Testing shall include "Seam Strength" and "Peel Adhesion". These terms are defined in the specifications. The minimum acceptable values to be obtained in these tests are indicated in the WMNA specifications (see Appendix A). At least 5 specimens shall be tested in each shear and peel. Specimens shall be selected alternately by test from the samples (i.e., peel, shear, peel, shear...). A passing test shall meet the minimum acceptable values in at least 4 of the 5 specimens tested for each method.

The Geosynthetic QAL shall provide verbal test results no more than 24 hours after they receive the samples. The Geosynthetic QAE shall review laboratory test results as soon as they become available, and make appropriate recommendations to the Project Manager.

4.8.7 Destructive Test Failure Procedures

The following procedures shall apply whenever a sample fails a destructive test, whether that test is conducted by the Geosynthetic QAL, or by field tensiometer. The Installer has two options:

1. The Installer can repair the seam between any two passing test locations.
2. The Installer can trace the welding path to an intermediate location (at 10 ft (3 m) minimum from the point of the failed test in each direction) and take a sample with a 1 in (25 mm) wide die for an additional field test at each location. If these additional samples pass the test, then full laboratory samples are taken. If these laboratory samples pass the tests, then the seam is repaired between these locations. If either sample fails, then the process is repeated to establish the zone in which the seam should be repaired.

All acceptable repaired seams shall be bound by two locations from which samples passing laboratory destructive tests have been taken. Passing laboratory destructive tests of trial seam samples taken as indicated in Section 4.6.4 may be used as a boundary for the failing seam. In cases exceeding 150 ft (50 m) of repaired seam, a sample taken from the zone in which the seam has been repaired must pass destructive testing. Repairs shall be made in accordance with Section 4.9.

The Geosynthetic QAC shall document all actions taken in conjunction with destructive test failures.

4.9 DEFECTS AND REPAIRS

4.9.1 Identification

All seams and non-seam areas of the geomembrane shall be examined by the Geosynthetic QAC for identification of defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Because light reflected by the geomembrane helps to detect defects, the surface of the geomembrane shall be clean at the time of examination. The geomembrane surface shall be cleaned by the Installer if the amount of dust or mud inhibits examination.

4.9.2 Evaluation

Each suspect location both in seam and non-seam areas shall be nondestructively tested using the methods described in Section 4.7 as appropriate. Each location which fails the nondestructive testing shall be marked by the Geosynthetic QAC and repaired by the Installer. Work shall not proceed with any materials which will cover locations which have been repaired until appropriate nondestructive and laboratory test results with passing values are available.

4.9.3 Repair Procedures

Any portion of the geomembrane exhibiting a flaw, or failing a destructive or nondestructive test, shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be agreed upon between the Project Manager, Installer, and Geosynthetic QAE.

1. The repair procedures available include:

    a. Patching, used to repair large holes, tears, undispersed raw materials, and contamination by foreign matter.
    b. Spot welding or seaming, used to repair small tears, pinholes, or other minor, localized flaws.
    c. Capping, used to repair large lengths of failed seams.
    d. Extrusion welding the flap, used to repair areas of inadequate fusion seams, which have an exposed edge. Repairs of this type shall be approved by the Geosynthetic QAE and shall not exceed 50 ft (15 m) in length.
    e. Removing bad seam and replacing with a strip of new material welded into place.

2. For any repair method, the following provisions shall be satisfied:

    a. Surfaces of the geomembrane which are to be repaired using extrusion methods shall be abraded no more than one hour prior to the repair.
    b. All surfaces shall be clean and dry at the time of the repair.

c. All seaming equipment used in repairing procedures shall meet the requirements of the project QAP.
d. Patches or caps shall extend at least 6 in (150 mm) beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately 3 in (75 mm).

4.9.4 Repair Verification

Each repair shall be numbered and logged. Each repair shall be nondestructively tested using the methods described in Section 4.7 as appropriate. Repairs which pass the nondestructive test shall be taken as an indication of an adequate repair. Repairs more than 150 ft long may be of sufficient extent to require destructive test sampling, at the discretion of the Geosynthetic QAE. Failed tests indicate that the repair shall be redone and retested until a passing test results. The Geosynthetic QAC shall observe all nondestructive testing of repairs and shall record the number of each repair, date, and test outcome.

4.9.5 Large Wrinkles

When seaming of the geomembrane is completed, and prior to placing overlying materials, the Geosynthetic QAE shall indicate to the Project Manager which wrinkles should be cut and reseamed by the Installer. The number of wrinkles to be repaired should be kept to an absolute minimum. Therefore, wrinkles should be located during the coldest part of the installation process, while keeping in mind the forecasted weather to which the uncovered geomembrane may be exposed. Wrinkles are considered to be large when the geomembrane can be folded over on to itself. This is generally the case for a wrinkle that extends 12 in. from the subgrade. Seams produced while repairing wrinkles shall be tested as outlined above.

When placing overlying material on the geomembrane, every effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather available. In addition, small wrinkles should be isolated and covered as quickly as possible to prevent their growth. The placement of cover materials shall be observed by the Geosynthetic QAC to ensure that wrinkle formation is minimized.

4.10 GEOMEMBRANE PROTECTION

The quality assurance procedures indicated in this Section are intended only to assure that the installation of adjacent materials does not damage the geomembrane. The quality assurance of the adjacent materials themselves should be covered in separate sections of the project QAP as necessary.

4.10.1 Soils

A copy of the specifications prepared by the Designer for placement of soils shall be given to the Geosynthetic QAE by the Project Manager. The Geosynthetic QAE shall verify that these specifications are consistent with the state-of-practice such as:

1. Placement of soils on the geomembrane shall not proceed at an ambient temperature below 32°F (0°C) nor above 104°F (40°C) unless otherwise specified.
2. Placement of soil on the geomembrane should be done during the coolest part of the day to minimize the development of wrinkles in the geomembrane.
3. A geotextile or other cushion approved by the Designer is generally required between aggregate and the geomembrane.
4. Equipment used for placing soil shall not be driven directly on the geomembrane.
5. A minimum thickness of 1 ft (0.3 m) of soil is specified between a light dozer (ground pressure of 5 psi (35 kPa) or lighter) and the geomembrane.
6. In any areas traversed by any vehicles other than low ground pressure vehicles approved by the Project Manager, the soil layer shall have a minimum thickness of 3 ft (0.9 m). This requirement may be waived if provisions are made to protect the geomembrane through an engineered design. Drivers shall proceed with caution when on the overlying soil and prevent spinning of tires or sharp turns.

The Geosynthetic QAC shall measure soil thickness and verify that the required thicknesses are present. The Geosynthetic QAC must also verify that final thicknesses are consistent with the design and verify that placement of the soil is done in such a manner that geomembrane damage is unlikely. The Geosynthetic QAE shall inform the Project Manager if the above conditions are not fulfilled.

4.10.2 Concrete

A copy of the specifications prepared by the Designer for placement of concrete shall be given by the Project Manager to the Geosynthetic QAC. The Geosynthetic QAC shall verify that these specifications are consistent with the state-of-practice, including the use of geosynthetic layers between concrete and geomembrane. The Geosynthetic QAC shall verify that geosynthetic layers are placed between the concrete and the geomembrane according to design specifications. The Geosynthetic QAC will also verify that construction methods used are not likely to damage the geomembrane.

4.10.3 Sumps and Appurtenances

A copy of the plans and specifications prepared by the Designer for sumps and appurtenances shall be given by the Project Manager to the Geosynthetic QAC. The Geosynthetic QAC shall review these plans and verify that:

1. Installation of the geomembrane in sump and appurtenant areas, and connection of geomembrane to sumps and appurtenances have been made according to specifications.

2. Extreme care is taken while welding around appurtenances since neither non-destructive nor destructive testing may be feasible in these areas.
3. The geomembrane has not been visibly damaged while making connections to sumps and appurtenances.

The Geosynthetic QAC shall inform the Project Manager in writing if the above conditions are not fulfilled.

5.0 GEOTEXTILES

5.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct a periodic inspection of the Manufacturer's plant. In addition, the Project Manager, or his designated representative, may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geotextile rolls for that particular project. The purpose of the plant inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geotextile.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geotextile, roll number, and roll dimensions.
6. Verification that the geotextiles are inspected continuously for the presence of needles using a metal detector.

A report describing the inspection will be retained by WMNA for periodic inspections and by the Project Manager for project-specific inspections.

5.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geotextile, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant) and identification (brand name and number) of the resin used to manufacture the geotextile.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geotextile meets the Manufacturer's resin specifications.
4. Reports on quality control tests conducted by the Manufacturer to verify that the geotextile manufactured for the project meets the project specifications.
5. A statement indicating that the reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness.
6. A list of the materials which comprise the geotextile, expressed in the following categories as percent by weight: base polymer, carbon black, other additives.

7. A specification for the geotextile which includes all properties contained in the project specifications measured using the appropriate test methods.
8. Written certification that minimum average roll values given in the specification are guaranteed by the Manufacturer.
9. For non-woven geotextiles, written certification that the Manufacturer has continuously inspected the geotextile for the presence of needles and found the geotextile to be needle free.
10. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

    a. Mass per unit area
    b. Grab strength
    c. Trapezoidal tear strength
    d. Burst strength
    e. Puncture strength
    f. Thickness

    Quality control tests shall be performed in accordance with the test methods specified in the project specifications for at least every 100,000 ft^2 (10,000 m^2) of geotextile produced.

The Manufacturer shall identify all rolls of geotextiles with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
4. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum average roll properties meet the project specifications.

5.3 CONFORMANCE TESTING

Upon delivery of the rolls of geotextiles, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geotextile. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to ensure conformance to the project specifications.

At a minimum, the following conformance tests shall generally be performed on geotextiles:

1. Mass per unit area
2. Grab strength
3. Trapezoidal tear strength
4. Burst strength
5. Puncture strength
6. Thickness

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

5.3.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first complete revolution of fabric on the roll. Samples shall not be taken from any portion of a roll which has been subjected to excess pressure or stretching. Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow. All lots of material and the particular test sample that represents each lot should be defined before the samples are taken.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geotextile.

5.3.2 Test Results

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geotextile.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAE shall be

responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

5.4 GEOTEXTILE DEPLOYMENT

During shipment and storage, the geotextile shall be protected from ultraviolet light exposure, precipitation or other inundation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions. Geotextile rolls shall be shipped and stored in relatively opaque and watertight wrappings. Wrappings shall be removed shortly before deployment.

The Geosynthetic QAC shall observe rolls upon delivery at the site and any deviation from the above requirements shall be reported to the Project Manager.

The Installer shall handle all geotextiles in such a manner as to ensure they are not damaged in any way, and the following shall be complied with:

1. On slopes, the geotextiles shall be securely anchored and then rolled down the slope in such a manner as to continually keep the geotextile sheet in tension.
2. In the presence of wind, all geotextiles shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geotextiles shall be cut using a geotextile cutter (hook blade) only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geotextiles.
4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geotextile.
5. During placement of geotextiles, care shall be taken not to entrap, in or beneath the geotextile, stones, excessive dust, or moisture that could damage the geomembrane, cause clogging of drains or filters, or hamper subsequent seaming.
6. A visual examination of the geotextile shall be carried out over the entire surface, after installation, to ensure that no potentially harmful foreign objects, such as needles, are present.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

5.5 SEAMING PROCEDURES

On slopes steeper than 10 (horizontal):1 (vertical), all geotextiles shall be continuously sewn (i.e., spot sewing is not allowed). Geotextiles shall be overlapped a minimum of 3 in (75 mm) prior to seaming. In general, no horizontal seams shall be allowed on side slopes (i.e. seams shall be along, not across, the slope), except as part of a patch.

On bottoms and slopes shallower than 10 (horizontal):1 (vertical), geotextiles shall be seamed as indicated above (preferred), or thermally bonded with the written approval of the Project Manager.

The Installer shall pay particular attention at seams to ensure that no earth cover material could be inadvertently inserted beneath the geotextile.

Any sewing shall be done using polymeric thread with chemical and ultraviolet light resistance properties equal to or exceeding those of the geotextile. Sewing shall be done using machinery and stitch types specified in the project specifications or as approved in writing by the Project Manager and the Geosynthetic QAE.

5.6 DEFECTS AND REPAIRS

Any holes or tears in the geotextile shall be repaired as follows:

On slopes, a patch made from the same geotextile shall be sewn into place in accordance with the project specifications. Should any tear exceed 10% of the width of the roll, that roll shall be removed from the slope and replaced.

Care shall be taken to remove any soil or other material which may have penetrated the torn geotextile.

The Geosynthetic QAC shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

5.7 GEOTEXTILE PROTECTION

All soil materials located on top of a geotextile shall be deployed in such a manner as to ensure:

1. The geotextile and underlying lining materials are not damaged.
2. Minimal slippage of the geotextile on underlying layers occurs.
3. No excess tensile stresses occur in the geotextile.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.10.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

If portions of the geotextile are exposed, the Geosynthetic QAC may periodically place two (or more, at his discretion) marks on the geotextile 10 ft (3 m) apart along the slope and measure the elongation of the geotextile during the placement of soil. This data shall be reported to the Project Manager.

6.0 GEONETS

6.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct a periodic inspection of the manufacturer's plant. In addition, the Project Manager, or his designated representative may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geonet rolls for that particular project. The purpose of the inspection is to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geonet.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geonet, roll number, and roll dimensions.

A report describing the inspection will be retained by WMNA for periodic inspections and by the Project Manager for project-specific inspections.

6.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geonet, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geonet meets the WMNA specifications (see Appendix A).
4. Reports on quality control tests conducted by the Manufacturer to verify that the geonet manufactured for the project meets the project specifications.
5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2% by weight.
6. A list of the materials which comprise the geonet, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
7. A specification for the geonet which includes all properties contained in the WMNA specifications (see Appendix A) measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
9. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificates shall include roll identification numbers, sampling procedures and results of quality control tests. At a minimum, results shall be given for:

    a. Density
    b. Mass per unit area
    c. Thickness
    d. Carbon black content

    Quality control tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A), for every 40,000 ft^2 (4,000 m^2) of geonet produced.

The Manufacturer shall identify all rolls of geonets with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurements of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum properties meet the WMNA specifications (see Appendix A).

6.3 CONFORMANCE TESTING

Upon delivery of the rolls of geonet, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geonet. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the WMNA specifications (see Appendix A).

At a minimum, the following tests shall be performed:

1. Density
2. Mass per unit area
3. Thickness

These conformance tests shall be performed in accordance with the test methods specified in the WMNA specifications (see Appendix A). Other conformance tests may be required by the project specifications.

6.3.1 Sampling Procedures

The rolls to be sampled shall be selected by the Geosynthetic QAC. Samples shall be taken across the entire width of the roll and shall not include the first 3 ft (1 m). Unless otherwise specified, samples shall be 3 ft (1 m) long by the roll width. The Geosynthetic QAC shall mark the machine direction on the samples with an arrow.

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geonet.

6.3.2 Test Results

All conformance test results shall be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geonet.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAE shall be responsible for checking that all test results meet or exceed the property values listed in the project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test should be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

6.4 GEONET DEPLOYMENT

The Geosynthetic QAC shall examine rolls upon delivery and any deviation from the above requirements shall be reported to the Project Manager.

Geonet cleanliness is essential to its performance. Therefore, the geonet rolls should be protected against dust and dirt during shipment and storage.

The Geosynthetic QAC shall verify that the geonet is free of dirt and dust prior to installation. The Geosynthetic QAC shall report the outcome of this verification to the Project Manager, and if the geonet is judged dirty or dusty, it shall be washed by the Installer prior to installation. Washing operations shall be observed by the Geosynthetic QAC and improper washing operations shall be reported to the Project Manager.

The Installer shall handle all geonet in such a manner as to ensure that it is not damaged in any way, and the following shall be complied with:

1. On slopes, the geonet shall be secured and rolled down the slope in such a manner as to continually keep the geonet sheet in tension. If necessary, the geonet shall be positioned by hand after being unrolled to minimize wrinkles.

2. In the presence of wind, all geonet shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Unless otherwise specified, geonet shall not be welded to geomembrane.

4. Geonet shall only be cut using scissors or other cutting tools approved by the Project Manager that will not damage the underlying geosynthetics. Care shall be taken not to leave tools in the geonet.

5. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geonet.

6. During placement of geonet, care shall be taken not to entrap in the geonet dirt or excessive dust that could cause clogging of the drainage system, and/or stones that could damage the adjacent geomembrane. If dirt or excessive dust is entrapped in the geonet, it should be hosed clean prior to placement of the next material on top of it. In this regard, care shall be taken with the handling of sandbags, to prevent rupture or damage of the sandbag.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

6.5 SEAMS AND OVERLAPS

Adjacent geonet shall be joined according to construction drawings and specifications. At a minimum, the following requirements shall be met:

1. Adjacent rolls shall be overlapped by at least 4 in (100 mm).
2. Overlaps shall be secured by tying.
3. Tying can be achieved by plastic fasteners or polymer braid. Tying devices shall be white or yellow for easy inspection. Metallic devices are not allowed.
4. Tying shall be every 5 ft (1.5 m) along the slope, every 6 in (0.15 m) in the anchor trench, and every 6 in (0.15 m) along end-to-end seams on the base of the landfill.
5. In general, no horizontal seams shall be allowed on side slopes.
6. In the corners of the side slopes of rectangular landfills, where overlaps between perpendicular geonet strips are required, an extra layer of geonet shall be unrolled along the slope, on top of the previously installed geonet, from top to bottom of the slope.
7. When more than one layer of geonet is installed, joints shall be staggered.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

When several layers of geonet are stacked, care shall be taken to prevent strands of one layer from penetrating the channels of the next layer, thereby significantly reducing the transmissivity. This cannot happen if stacked geonet are placed in the same direction. A stacked geonet shall never be laid in perpendicular directions to the underlying geonet (unless otherwise specified by the Designer).

6.6 DEFECTS AND REPAIRS

Any holes or tears in the geonet shall be repaired by placing a patch extending 1 ft (0.3 m) beyond the edges of the hole or tear. The patch shall be secured to the original geonet by tying every 6 in (0.15 m). Tying devices shall be as indicated in Section 6.5. If the hole or tear width across the roll is more than 50% of the width of the roll, the damaged area shall be repaired as follows:

1. On the base of the landfill, the damaged area shall be cut out and the two portions of the geonet shall be joined as indicated in Section 6.5.
2. On sideslopes, the damaged geonet shall be removed and replaced.

The Geosynthetic QAC shall observe any repair and report any noncompliance with the above requirements in writing to the Project Manager.

6.7 GEONET PROTECTION

Soil should never be placed in direct contact with geonet. Soil materials near the geonet shall be placed in such a manner as to ensure:

1. The geonet and underlying lining materials are not damaged.
2. Minimal slippage of the geonet on underlying layers occurs.
3. No excess tensile stresses occur in the geonet.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.10.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

7.0 GEOGRIDS

7.1 MANUFACTURING PLANT INSPECTION

WMNA will conduct a periodic inspection of the manufacturer's plant. In addition, the Project Manager, or his designated representative may visit the manufacturing plant for a project-specific inspection if deemed necessary. If possible, the project-specific inspection shall be prior to or during the manufacturing of the geogrid rolls for that particular project. The purpose of this inspection shall be to review the manufacturing process and quality control procedures.

The manufacturing plant inspection shall include:

1. Verification that properties guaranteed by the Manufacturer meet all WMNA and/or project specifications.
2. Verification that the measurement of properties by the Manufacturer is properly documented and test methods used are acceptable.
3. Spot inspection of the rolls and verification that they are free of imperfections or any sign of contamination by foreign matter.
4. Review of packaging, handling, storage, and transportation procedures and verification that these procedures will not damage the geogrid.
5. Verification that roll packages have a label indicating the name of the manufacturer, type of geogrid, roll number, and roll dimensions.

A report describing the inspection will be retained by WMNA for periodic inspections and by the Project Manager for project-specific inspections.

7.2 QUALITY CONTROL DOCUMENTATION

Prior to the installation of any geogrid, the Manufacturer or Installer shall provide the Project Manager with the following information:

1. The origin (resin supplier's name and resin production plant), identification (brand name and number), and production date of the resin.
2. Copies of the quality control certificates issued by the resin supplier.
3. Reports on tests conducted by the Manufacturer to verify that the quality of the resin used to manufacture the geogrid meets the WMNA specifications (see Appendix A).
4. Reports on quality control tests conducted by the Manufacturer to verify that the geogrid manufactured for the project meets the project specifications.
5. A statement indicating that the amount of reclaimed polymer added to the resin during manufacturing was done with appropriate cleanliness and does not exceed 2% by weight.
6. A list of the materials which comprise the geogrid, expressed in the following categories as percent by weight: polyethylene, carbon black, other additives.
7. A specification for the geogrid which includes all properties contained in the project specifications measured using the appropriate test methods.

8. Written certification that minimum values given in the specification are guaranteed by the Manufacturer.
9. Quality control certificates, signed by a responsible party employed by the Manufacturer. The quality control certificate shall include roll identification numbers, sampling procedures, and results of quality control tests. At a minimum, results shall be given for:

    a. Mass per unit area
    b. Measurement of spacing between strands
    c. Wide strip tensile strength
    d. Node strength

    Quality control tests shall be performed in accordance with the test methods specified in the project specifications, for every 40,000 ft^2 (4,000 m^2) of geogrid produced.

The Manufacturer shall identify all rolls of geogrids with the following:

1. Manufacturer's name
2. Product identification
3. Roll number
5. Roll dimensions

The Geosynthetic QAE shall review these documents and shall report any discrepancies with the above requirements to the Project Manager. The Geosynthetic QAE shall verify that:

1. Property values certified by the Manufacturer meet all of its guaranteed specifications.
2. Measurement of properties by the Manufacturer are properly documented and that the test methods used are acceptable.
3. Quality control certificates have been provided at the specified frequency for all rolls, and that each certificate identifies the rolls related to it.
4. Roll packages are appropriately labeled.
5. Certified minimum properties meet the project specifications.

7.3 CONFORMANCE TESTING

Upon delivery of the rolls of geogrid, the Geosynthetic QAC shall ensure that conformance test samples are obtained for the geogrid. These samples shall then be forwarded to the Geosynthetic QAL for testing to ensure conformance to the project specifications.

At a minimum, the following conformance tests shall be performed on geogrid:

1. Mass per unit area
2. Measurement of spacing between strands
3. Wide strip tensile strength

4. Node strength

These conformance tests shall be performed in accordance with the test methods specified in the project specifications. Other conformance tests may be required by the project specifications.

7.3.1 Sampling Procedures

A lot shall be defined as a group of consecutively numbered rolls from the same manufacturing line. Alternatively, a lot may be designated by the Geosynthetic QAC based on a review of all roll information including quality control documentation and manufacturing records.

Unless otherwise specified, samples shall be taken at a rate of one per lot, not to exceed one conformance test per 100,000 ft^2 (10,000 m^2) of geogrid.

7.3.2 Test Results

All conformance test results must be reviewed and accepted or rejected by the Geosynthetic QAE prior to the deployment of the geogrid.

The Geosynthetic QAE shall examine all results from laboratory conformance testing and shall report any nonconformance to the Project Manager. The Geosynthetic QAC shall be responsible for checking that all test results meet or exceed the minimum property values listed in project specifications.

If the Manufacturer has reason to believe that failing tests may be the result of the Geosynthetic QAL incorrectly conducting the tests, the Manufacturer may request that the sample in question be retested by the Geosynthetic QAL with a technical representative of the Manufacturer present during the testing. This retesting shall be done at the expense of the Manufacturer. Alternatively, the Manufacturer may have the sample retested at two different WMNA approved Geosynthetic QALs at the expense of the Manufacturer. If both laboratories produce passing results, the material shall be accepted. If both laboratories do not produce passing results, then the original Geosynthetic QAL's test results shall be accepted. The use of these procedures for dealing with failed test results is subject to the approval of the Project Manager.

If a test result is in nonconformance, all material from the lot represented by the failing test shall be considered out of specification and rejected. Alternatively, at the option of the Project Manager, additional conformance test samples may be taken to "bracket" the portion of the lot not meeting specification (note that this procedure is valid only when all rolls in the lot are consecutively produced and numbered from one manufacturing line). To isolate the out of specification material, additional samples must be taken from rolls that have roll numbers immediately adjacent to the roll that was sampled and failed. If both additional tests pass, the roll that represents the initial failed test and the roll

manufactured immediately after that roll (next larger roll number) shall be rejected. If one or both of the additional tests fail, then the entire lot shall be rejected or the procedure repeated with two additional tests that bracket a greater number of rolls within the lot.

7.4 GEOGRID DEPLOYMENT

The Installer shall handle all geogrid in such a manner as to ensure it is not damaged in any way, and the following shall be complied with:

1. On slopes, the geogrid shall be secured and rolled down the slope in such a manner as to continually keep the geogrid in tension.

2. In the presence of wind, all geogrids shall be weighted with sandbags or the equivalent. Such sandbags shall be installed during deployment and shall remain until replaced with cover material.

3. Geogrid shall be cut using scissors only. If in place, special care shall be taken to protect other materials from damage which could be caused by the cutting of the geogrid.

4. The Installer shall take any necessary precautions to prevent damage to underlying layers during placement of the geogrid.

The Geosynthetic QAC shall note any noncompliance and report it to the Project Manager.

7.5 SEAMS AND OVERLAPS

The geogrid, where used, shall be placed in continuous pieces downslope. No lateral joining is required. Edge to edge placement shall be sufficient.

Where geogrid is joined end to end, a splice approved by the manufacturer shall be used. The splice shall not have any metallic components.

7.6 REPAIRS

Any damaged roll of geogrid shall be discarded. No repairs shall be allowed.

7.7 SOIL MATERIALS PLACEMENT

All soil materials located on top of a geogrid shall be deployed in such a manner as to ensure:

1. The geogrid and underlying materials are not damaged.
2. Minimal slippage of the geogrid on underlying layers occurs.

Unless otherwise specified by the Designer, all lifts of soil material shall be in conformance with the guidelines given in Section 4.10.1.

Any noncompliance shall be noted by the Geosynthetic QAC and reported to the Project Manager.

APPENDIX A

WMNA SPECIFICATIONS FOR HDPE GEOSYNTHETICS

June 15, 1990

TABLE A-1
HDPE GEOMEMBRANE PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE	ALL THICKNESSES	TEST METHOD
Thickness	minimum avg	mils	40 60 80 100		
Thickness	minimum	mils	36 54 72 90		ASTM D751*
Density (geomembrane)	minimum	g/cc	-------- 0.940 --------		ASTM D1505 or ASTM D792
Melt Index (resin)	range	*g/10 min	------- 0.1 - 1.1 ------		ASTM D1238 (Condition 190/216)
Tensile Properties: (each direction)					ASTM D638*
1. Yield strength	minimum	lb/in	88 132 176 220	2200 psi	
2. Break strength	minimum	lb/in	152 228 304 380	3800 psi	
3. Elongation at yield	minimum	%	---------- 12 ----------		
4. Elongation at break	minimum	%	--------- 600 ---------		
Tear Strength	minimum	lb	28 42 56 70	700 lb/in	ASTM D1004 Die C
Puncture Resistance	minimum	lb	72 108 144 180	1800 lb/in	ASTM D4833
Low Temperature	maximum	deg. C	--------- (-60) ---------		ASTM D746
Carbon Black Content	range	%	-------- 2.0 to 3.0 -------		ASTM D1603
Carbon Black Dispersion	rating	N/A	------ A-1 or A-2 -------		ASTM D3015
Dimensional Stability (each direction)	max. change	%	---------- 2.0 ----------		ASTM D1204*
Environmental Stress Crack	minimum	hours	--------- 2000 ----------		ASTM D1693*

TABLE A-2
HDPE SEAM PROPERTIES

PROPERTY	QUALIFIER	UNIT	SPECIFIED VALUE	ALL THICKNESSES	TEST METHOD
Thickness	minimum avg.	mils	40 60 80 100		
Bonded Seam Strength	mimimum	lb/in	88 132 176 220	2200 psi	ASTM D4437*
Peel Adhesion:					
Fusion	mimimum	lb/in	60 90 120 150	1500 psi	ASTM D4437*
Extrusion	mimimum	lb/in	52 78 104 130	1300 psi	ASTM D4437*

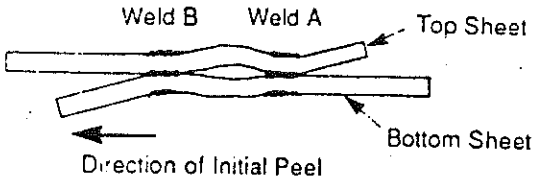
NOTE:

* Test methods as modified on the following page

NOTES FOR TABLE A-1

PROPERTY	TEST METHOD	MODIFICATIONS
Thickness	ASTM D751	Measure thickness at one foot intervals across the width of the roll (perpendicular to the machine direction) and report average, standard deviation, and lowest individual readings.
Tensile Properties	ASTM D638	Type IV Die. ASTM D638 test specimen shall be used. The grip separation shall be 2.5 inches. This test does not require the use of extensometers. The rate of grip separation will be 2 inches per minute. A gauge length of 1.3 inches for yield values, and 2.5 inches for break values shall be used to calculate elongation from grip movement.
Dimensional Stability	ASTM D1204	100°C for 15 minutes
Environmental Stress Crack	ASTM D1693	Use Condition "B" (50°C) with the exception of the following modifications: 1. Use an aqueous solution containing 10% igepal by volume. 2. The final product shall be tested as produced, regardless of thickness. 3. The notch depth shall be as stated in condition B, 0.30 to 0.40 mm (0.012 to 0.015 in), for all sheet thicknesses. 4. Cut five (5) specimens with the length parallel to the machine direction (MD) and five (5) with the length parallel to the transverse direction (TD). 5. The failure time shall be the time in hours to the first specimen failure.
Bonded Seam Strength and Peel Adhesion	ASTM D4437	For shear tests, the sheet shall yield before failure of the seam. For peel adhesion, seam separation shall not extend more than 10% into the seam. For either test, testing shall be discontinued when the sample has visually yielded. Sample failure shall conform to a passing configuration as outlined in Figure A-1.

Schematic of Untested Specimen



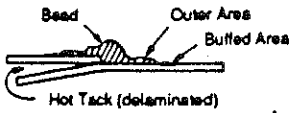
Types of Break	Locus-of-Break Code	Break Description	Classification[a]
	AD	Adhesion failure.	Non-FTB
	BRK	Break in sheeting. Break can be in either top or bottom sheet.	FTB
	SE1	Break at outer edge of seam. Break can be in either top or bottom sheet.	FTB
	SE2	Break at inner edge of seam through both sheets.	FTB
	AD-BRK	Break in first seam after some adhesion failure. Break can be in either the top or bottom sheet.	FTB

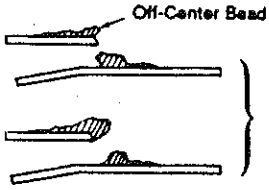
[a] FTB = Film - Tear Bond

NOT TO SCALE

After EPA/600/2-88/052
Lining of Waste Containment and Other Surface Impoundment Facilities

Schematic of Untested Specimen



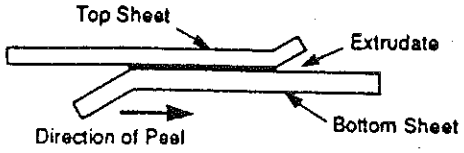
Types of Breaks	Locus-of-Break Code	Break Description	Classification[a]
	AD1	Failure in adhesion. Specimens may also delaminate under the bead and break through the thin extruded material in the outer area.	Non-FTB
	AD2	Failure in adhesion.	Non-FTB
	AD-WLD	Break through the fillet. Breaks through the fillet range from breaks starting at the edge of the top sheet to breaks through the fillet after some adhesion failure between the fillet and the bottom sheet.	Non-FTB[b]
	SE1	Break at seam edge in the bottom sheet. Specimens may break anywhere from the bead/outer area edge to the outer area/buffed area edge. (Applicable to shear only).	FTB
	SE2	Break at seam edge in the top sheet. Specimens may break anywhere from bead/outer area edge to the outer area/buffed area edge.	FTB
	SE3	Break at seam edge in the bottom sheet. (Applicable to peel only).	FTB
	BRK1	Break in the bottom sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area. (Applicable to shear only).	FTB
	BRK2	Break in the top sheeting. A "B" in parentheses following the code means the specimen broke in the buffed area.	FTB
	AD-BRK	Break in the bottom sheeting after some adhesion failure between the fillet and the bottom sheet. (Applicable to peel only).	FTB
	HT	Break at the edge of the hot tack for specimens which could not be delaminated in the hot tack.	No Test

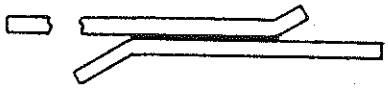
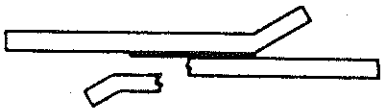
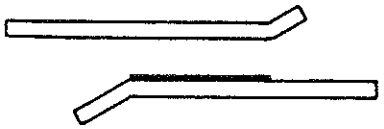
[a] FTB = Film - Tear Bond.

[b] Acceptance of AD-WLD breaks may depend on whether test values meet a minimum specification value and not on classification as a FTB or non-FTB break.

After EPA/600/2-88/052
Lining of Waste Containment and Other Surface Impoundment Facilities

Schematic of Untested Specimen



Location of Break	Locus-of-Break Code	Break Description	Classification[a]
	BRK	Break in sheeting outside weld area. Break can be in either the top or bottom sheet	FTB
	SE1	Break in top sheet at seam edge.	FTB
	SE2	Break in bottom sheeting at seam edge	FTB
	SE3	Break in bottom sheeting at seam edge. (Applicable to peel only).	FTB
	AD-BRK	Break in sheeting after some adhesion failure between extrudate and surface of the sheeting. Break can be in either the top or bottom sheet.	FTB
	AD	Failure in adhesion between the extrudate and the sheeting surface.	Non-FTB

[a] FTB = Film - Tear Bond

After EPA/600/2-88/052
Lining of Waste Containment and Other Surface Impoundment Facilities

TABLE A-3
HDPE GEONET PROPERTIES

PROPERTY	QUALIFIER	UNIT	VALUE	TEST METHOD
Polyethylene Content	minimum	%	95	———
Resin Density	minimum	g/cc	0.935	ASTM D1505
Carbon Black Content	range	%	2.0 – 3.0	ASTM D1603
Melt Index	maximum	g/10 min	1.0	ASTM D1238 (Condition 190/216)
Thickness	minimum	mils	200	ASTM D1777
Weight per Sq Ft	minimum	lb/ft^2	0.16	ASTM D3776 (option C)
Tensile Strength	minimum	lb/in	40	ASTM D1682[1]
Transmissivity	minimum	m^2/sec	1×10^{-3}	ASTM D4716[2]

1. Test method modified as follows:
   a) Use 4 in x 8 in specimens.
   b) Use test rate of 8 in/min.
   c) Continue test until first strand separates completely.
   d) Report averages of 5 tests in each direction (machine and cross).

2. Gradient = 1.0, Confining Pressure = 15,000 psf, Measured between two steel plates one hour after application of confining pressure.

APPENDIX B

FINGERPRINTING PROTOCOL FOR HDPE GEOSYNTHETICS

June 15, 1990

Fingerprinting Protocol for High Density Polyethylene Geosynthetics

The following tests must be performed by the Manufacturer of any HDPE geosynthetic for identification of the Manufacturer's product:

Parameter	Method
Density	ASTM D792 or ASTM D1505
Melt Flow Ratio	ASTM D1238
Percent Volatiles	ASTM D3030
Percent extractables with methyl ethyl ketone (MEK) and N-hexane	ASTM D3421
Structural comparison of extractables	Infrared (IR) Spectrophotometry
Composition Carbon black Ash Polymer Decomposition temperature Temperature at maximum rate of weight loss	Thermal Gravimetric Analysis (TGA)
Crystallinity Melting range and point at endotherm maximum	Differential Scanning Calorimetry (DSC)

The results of the above tests should be submitted to WMNA for pre-qualification of each product. Once the product is approved by WMNA, the manufacturer shall supply all WMNA projects with material made using the same HDPE resin type (within the resin Manufacturer's specifications) and manufacturing process as that of the material identified by the Manufacturer's product fingerprint. Any change in resin or manufacturing process must be approved by WMNA, based on a new fingerprint of the proposed material.

June 15, 1990

APPENDIX C

EXAMPLES OF GEOSYNTHETIC QUALITY ASSURANCE DOCUMENTATION

June 15, 1990

PANEL PLACEMENT FORM

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	PANEL NUMBER	ROLL NUMBER	PANEL LENGTH	PANEL WIDTH	PANEL LOCATION	PANEL CONDITION- VISUAL INSPECTION	COMMENTS

TRIAL WELD INFORMATION FORM

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	WEATHER/ WINDS	AMBIENT TEMP.	SEAMER INITIALS	MACHINE NUMBER	EXTRUSION WELDS		FUSION WELDS			PEEL VALUES (LBS/INCH)	PASS/ FAIL	COMMENTS
					BARREL TEMP. SET/PYRO	PREHEAT TEMP. SET/PYRO	WEDGE TEMP. SET/PYRO	MEASURED SPEED (FT/MIN)	WHEEL TENSION SETTING			

PANEL SEAMING CHECKLIST

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	WEATHER/ WINDS	AMBIENT TEMP.	SEAMER INITIALS	MACHINE NUMBER	SEAM TYPE	SEAM NUMBER	PANEL NUMBERS	SEAM LENGTH	TEMP. SETTING	MACHINE SPEED	COMMENTS

NON-DESTRUCTIVE SEAM TEST LOG

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	SEAM NUMBER	TESTER INITIALS	AIR TESTING					PASS/ FAIL	VACUUM BOX PASS/FAIL	COMMENTS
			PRESSURE (PSI)			TIME				
			START	END	DROP	START	END			

DESTRUCTIVE SEAM TEST LOG

PROJECT:	QUALITY ASSURANCE MONITOR:	MATERIAL DESCRIPTION:

DATE/ TIME	SAMPLE I.D.	SEAM NUMBER	TENS. NUMBER	OPERATOR INITIALS	FIELD TENSIOMETER PEEL VALUES (LBS/INCH)			PASS/ FAIL	DATE TO LAB PKG. SLIP NO.	LAB PASS/ FAIL	COMMENTS

CERTIFICATE OF COMPLETION

Type: Partial____ Substantial____ Final____

Project Name: _____

Site Name: _____

Date: _____

Description of Work Certified: _____

_____

_____

_____

I hereby certify that the above identified work has been inspected and that it has been properly installed. I further certify that all required testing has been completed and the results have been deemed acceptable by the Geosynthetic QAE. The work is suitable for its intended use.

GEOSYNTHETIC QAE

Signature: _____ Date: _____

Name (print): _____

Title: _____

Representing: _____

INSTALLER'S Representative

Signature: _____ Date: _____

Name (print): _____

Title: _____

Representing: _____

WMNA Representative

Signature: _____ Date: _____

Name (print): _____

Title: _____

Representing: _____

June 15, 1990

CERTIFICATE OF COMPLETION

OF SOIL SUBGRADE SURFACE

Date: _____

Project Name: _____

Site Name: _____

Location of Subgrade Surface to be Lined: _____

_____

_____

I hereby certify that the above area is suitable for the installation of geosynthetics, and that I shall be responsible for its integrity and suitability in accordance with the specifications from this date to completion of the installation.

INSTALLER'S REPRESENTATIVE

Name (print): _____ Date: _____

Title: _____

Representing: _____

Signature: _____

Acknowledged by:

GEOSYNTHETIC QUALITY ASSURANCE CONSULTANT

Name (print): _____ Date: _____

Title: _____

Representing: _____

Signature: _____

June 15, 1990

Attachment 5

Quality Assurance Monitoring,
Trench 11 Closure Cover Construction,
dated September, 1990

Golder Associates Inc.
CONSULTING ENGINEERS

REPORT ON

QUALITY ASSURANCE MONITORING
TRENCH 11 CLOSURE COVER CONSTRUCTION
ENVIRONMENTAL SANITARY LANDFILL
ELWOOD, ILLINOIS

SUBMITTED TO:

WASTE MANAGEMENT OF ILLINOIS, INC.
Environmental Sanitary Landfill
Route 2, Box 66
Laraway Road
Elwood, Illinois 6042

PREPARED BY:

GOLDER ASSOCIATES INC.
1809 North Mill Street, Suite C
Naperville, Illinois 60563
(708) 357-2066

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